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ECONOMIC IMPACTS ON U.S. AGRICULTURE FROM INSECTICIDE, FERTILIZER, SOIL LOSS, AND ANIMAL WASTE REGULATORY POLICIES

by

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INTRODUCTION

Agriculture interacts in many ways with the environment. Practices such as crop rotations, tillage operations, fertilizer and pesticide applications, and confined livestock operations are used in producing food. But, these practices can also alter the environment via runoff, sediment, nutrients, and toxic chemicals. As with other industries, agriculture's impact on the environment has come under close scrutiny as resource use has become a concern of many Americans.

The impact of agriculture on the land and water resources of the United States revolves around the use of the land, especially those management practices affecting soil erosion. Soil erosion is important because it reduces the productivity of the land and pollutes public waterways with sediment. The amount of soil that agronomists believe can be lost and still maintain productivity varies from one ton per acre per year on shallow soils to five tons on deep soils [17]. The elimination of sod crops and small grains from rotations causes increased erosion on sloping lands. Minimum tillage and the use of practices such as contouring, strip cropping, and terracing can serve as substitutes to protect the soil under these conditions but are not adequately employed by farmers. More than one-third of U.S. cropland is losing soil in excess of the limit at which soil productivity can be sustained over time [4]. This potential diminishing productivity of the nation's land base has been masked by improved technology, more effective pesticides, higher yielding crop varieties, and large applications of fertilizer. Today's shortages of resources, including energy, and the rising concern with environmental quality makes continued declines in soil productivity of more concern. Thus, there is the need for careful consideration of how agriculture is managing and can manage available land and water resources.

Objectives

This report is one in a sequence published by the Center for Agricultural and Rural Development (CARD) under a grant from the National Science Foundation's Research Applied to National Needs (RANN) concerned with policies for resource use in agriculture. The objective of this report is the analysis of policies designed to curb pollution problems created by excessive erosion of the soil, persistence of certain organochlorine insecticides in the environment, feedlot runoff, and the pollution of water supplies with nitrates.

The steps in the analysis include (1) identification of the changes in farm-level production practices required of agriculture to comply with the policy, (2) a measure of the shifts in comparative advantage created by the policy as evidenced by changes in regional production patterns, and (3) an account of changes in agriculture's use of available resources.

Alternatives

Each alternative analyzed in this report is concerned with the impact of an environmental restraint on U.S. agriculture. The alternatives are:

1. The Base Alternative. It extends ongoing trends to the year 1985. It does not require agriculture to meet any environmental goals.

2. The Soil Conservation Alternative. It requires agriculture to adopt cropping practices that limit soil erosion to levels set by soil scientists as necessary if the productivity of the land is to be maintained.

3. The Nitrogen Restriction Alternative. It reduces the possibility that agriculture is contributing excessive amounts of nitrogen to U.S. water supplies by restricting the use of nitrogen to 50 pounds per acre.

4. The Insecticide Restriction Alternative. It denies farmers the use of the organo-chlorine insecticides Chlordane and Heptachlor because of their persistence in the environment.

5. The Feedlot Runoff Control Alternative. It forces farmers to construct abatement facilities to prevent feedlot runoff from polluting nearby streams and rivers with organic matter and nutrients.

6. The High Export Alternative. It expands agricultural output to fully utilize the land and water resources available to U.S. agriculture without environmental controls.

7. The Restricted Export Alternative. It expands agricultural output to fully utilize the land and water resources available to U.S. agriculture with environmental controls.

Each of these alternatives is analyzed relative to stated levels of domestic and export demand. The alternatives are studied in terms of their impacts on farming practices, land and water use, interregional shifts in crop and livestock production patterns, inputs used in agriculture, environmental impact, production costs, conservation practices and soil loss levels, export capabilities, and other variables potentially affected by the imposition of environmental restrictions on the agricultural sector.

The Model

The alternatives are studied by means of an interregional linear programming model of U.S. agriculture. In the model, the land resources of the United States are divided into producing areas representing homogenous production conditions. A large number of crop and livestock production activities are defined within each of these producing areas. The demands for the commodities are defined at demand centers across the United States according to per capita consumption and population projections. When the model is solved, the land in each producing area is brought into production under the criterion of minimum cost, i.e., the most productive land is utilized first. This procedure allocates the production of crops and livestock to the producing areas to minimize the total cost of production and transportation incurred to meet domestic and export demands for agricultural products.

Methodology

The analysis of the alternatives is carried out in the following manner. First, a base alternative is solved which does not include any environmental restrictions on agriculture. Next, new alternatives are solved which include the selected environmental restraint. Then, the solutions from the base and the revised alternatives are compared and any differences attributed to the restraint.

II. AGRICULTURE AND THE ENVIRONMENT

This section briefly reviews some of the ways in which agriculture production practices can affect the environment. Many environmentally adverse effects can be limited by careful selection of the practices employed to produce food and fiber. The management of the soil is especially important because of the impacts which soil erosion can have on water quality.

The Soil

The soil is composed of varying quantities of sand, silt, and clay. The relative amount of each influences the properties of the soil. Soils with a large proportion of sand particles are highly permeable to air and water but have a limited storage capacity because water quickly drains from this type of soil. Soils with a high content of clay particles are poorly aerated and slow to absorb water because of limited large pore space.

Two soils with the same proportions of sand, silt, and clay can have different physical properties because of different soil structure--the arrangement of the individual particles into larger units. A desirable soil structure is one in which large pores extend from the soil surface to the water table. These large pores allow rapid infiltration and drainage of water and enhance the aeration of the subsoil. The retention and storage of water is associated with small pores that spread out into the soil from the large pores. The small pores permit the soil to hold water for later use by plants. A combination of large and small pores gives both adequate moisture-holding capacity and satisfactory water intake and drainage.

Organic matter in the soil binds particles together, determining the soil's structure and hence, its properties. A high organic matter content can reduce the difficulties in managing soils high in either sand or clay. The organic matter increases the water storage capacity of a sandy soil as it binds the large particles together creating small pores to retain the water. In a clay soil the organic matter binds the many small particles together into clusters creating the large pores needed for rapid infiltration of water. These clusters improve both the aeration of the soil and internal drainage of excess water.

Given the proportions of sand, silt, and clay, soil structure can be altered by the management practices of the farmer. Intensive tillage for row crops decreases soil particle aggregation because it increases the aeration of the soil. The increased aeration increases the rate of decomposition of the organic matter binding the soil particles. Small grains and sod crops have an opposite effect because of the reduced tillage operations.

Soil Erosion

Soil scientists have developed a soil loss equation to predict annual soil erosion based on the important factors influencing soil erosion [17]. The equation, known as the universal soil loss equation is:

$$A = R * K * LS * C * P$$

where: A is estimated annual soil loss in tons per acre, R is the rainfall, K is the erodibility factor for each soil, LS is the slope gradient and length factor, C is the crop management factor accounting for rotation and tillage practices, and P is the erosion control factor for conservative practices.

Soil scientists have defined soil loss tolerance levels for the soils in the United States. These tolerance levels denote the maximum rate of soil erosion that can be permitted without a decline in soil productivity. These rates range from one to five tons per acre per year, depending upon soil properties, soil depth, topography, and prior erosion.

Nitrogen

The role of nitrogen in agriculture has attracted special attention because of its alleged potential to harm the environment. Farmers have greatly increased the use of nitrogen fertilizer because of the high crop yields that can be obtained at a relatively low cost. This expanded use is viewed by some persons as a threat to the quality of surface and underground water supplies. Excessive amounts of nitrogen in the water may stimulate the growth of algae and can be a health hazard.

When nitrogen is in the nitrate form it may easily be leached from the soil by the water rather than attaching to the surfaces of the soil particles. Whether the nitrate ions are leached into ground water supplies depends upon several factors. Nitrogen in the nitrate form is readily taken up by plant roots; so, if there is a crop growing on the field to utilize the nitrates, then leaching will be minimized. When the soil is saturated with water there will not be any oxygen for the microorganisms in the soil. To obtain oxygen, microorganisms break down the nitrate ion. The nitrogen, thus freed, escapes into the atmosphere as a gas. This process is called denitrification. Most leaching of nitrate occurs in the spring before the crops are established and in the fall when the growing season is over and the crop is harvested. By restricting the large applications of nitrogen fertilizer to the growing season the farmers can reduce the leaching of nitrogen from their fields.

Nitrogen may be lost from a farmer's field in ways other than leaching and denitrification. Nitrogen can be removed from the field with sediments. There is a close relationship between soil and nutrient losses. Factors that increase or decrease soil losses will also result in corresponding changes in losses of nitrogen as well as other nutrients.

Runoff from Livestock Feedlots

When livestock are confined in feedlots and their wastes allowed to accumulate, a potential for pollution of waterways exists. Rainfall or snowmelt produces feedlot runoff which can carry nutrients and organic matter from the lots into streams. The organic matter creates a water quality problem as its decomposition reduces the amount of oxygen in the water. Fish and other water life are then affected. The nutrients carried into the waterways may stimulate excessive growth of algae and weeds.

A working feedlot does not pose a serious problem to underground water supplies via leaching of nitrogen. Research indicates that an adequately stocked feedlot creates conditions that limit nitrate leaching [9]. Livestock create a compacted layer below the feedlot surface which has no oxygen in it. The microorganisms in this compacted layer obtain their oxygen from the nitrates in the livestock wastes and release nitrogen gas to the atmosphere. The compacted layer thus forms a barrier restricting the leaching of nitrates. Hence, to minimize the possibility of nitrates being leached into the groundwater, the feedlot operator should keep animals in the lot as much as possible. When the lot is cleaned, the compacted layer should not be removed.

Pesticides

Soil insects live by breaking down and digesting plant residues producing the organic matter needed for good soil structure. The more persistent insecticides have the most effect on these soil insects. Soil insect populations can quickly recover following the application of very toxic but short-lived pesticides, but a longer time for recovery is required for persistent insecticides. Before these chemicals finally break down and disappear they may be concentrated by the soil insects. Aldrin and Dieldrin residues have been found in the bodies of earthworms at concentrations as much as 10 times higher than in the surrounding soil [5]. When such worms are a part of the diet of birds, the insecticides enter the food chain and affect other animals in the environment.

Insecticides and herbicides are used by farmers because of their effectiveness in controlling insect and weed infestations. This effectiveness and their low cost can lead to overuse. Insecticides are sometimes used as an insurance measure when there is no insect problem. Because of the low cost, the farmer does not lose much if there are no insects. However, if there is an infestation, then the farmer has protected his crop. With some organochlorine insecticides, this overuse becomes a matter of concern because their persistence allows the residues to build up in the soil and to cycle through the environment harming other forms of life.

III. THE MODEL

This section summarizes the construction and use of the linear programming model on which the analysis is based. The model, explained in detail in earlier documentations [7, 8], has four parts: (a) the land and water resources available to agriculture, (b) crop and livestock production activities for the transformation of these resources into agricultural commodities, (c) the commodity transportation network, and (d) the domestic and foreign demands for agricultural products. The model is solved with the objective of meeting the demands for agricultural products in a manner to minimize cost of producing and transporting the nation's agricultural products. The model assumes a competive equilibrium wherein all resources used in agriculture, except land and water, receive their market rate of return. The returns to land and water are determined endogenously in the model and may be higher or lower than market rates for a particular region.

The linear programming model has equations representing the limited amount of land in each of the five land classes in each of the 105 producing areas. (There are 10 land classes, 5 each for irrigated and dryland, in producing regions 48-105.) It also has water supply equations in the latter 58 regions. Finally, it has a set of demand equations for the endogenous commodities of the model in each of the 28 market regions. The equations state the amount of the resource used or the demand filled by each of the endogenous variables (activities) of the model. They thus assure that (a) the total requirements of the activities for resources will not exceed the supply of resources available, and (b) the commodity demands in the market regions will be fulfilled.

Regions of the Model

Four different sets of regions are used in this model. They are: (1) the data collection regions used in the development of the model data base, (2) the regions or producing areas within which the crop production activities of the model are defined, (3) the market regions within which the demands for the model are defined, and (4) the reporting regions for which the results are aggregated for reporting.

The data collections regions, shown in Figure 1, are based on county approximations of the major land resource areas used for data collection by the Soil Conservation Service, U.S. Department of Agriculture [8]. These regions delineate the land of the United States into 156 areas based on dominant soil type and management characteristics. Sets of weights based on relevant data relationships are used to transfer data from these regions into the producing regions to generate coefficients needed to define the model.

The 105 producing areas or regions shown in Figure 2 are derived from the Water Resource Council's 99 aggregated subareas [14]. The crop production sector and the model's land base are defined within these regions. The water sector for the Western United States is defined in producing areas 48 to 105.

The 28 market regions shown in Figure 3 are aggregations of contiguous producing areas. Each market region functions in the model as a demand

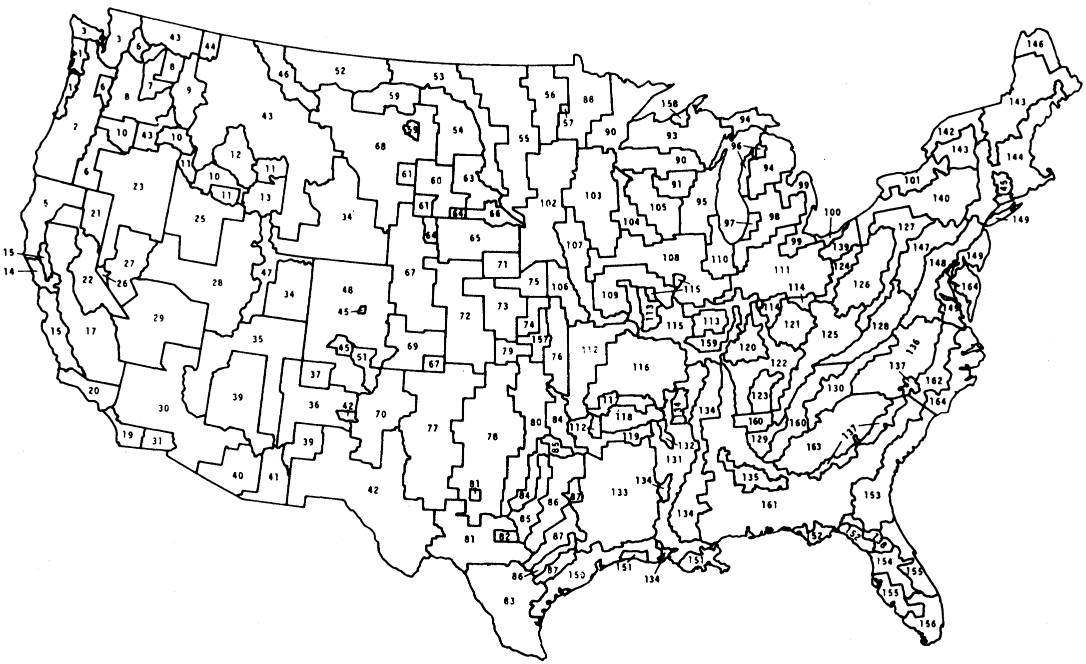

Figure 1. The SCS data collection areas

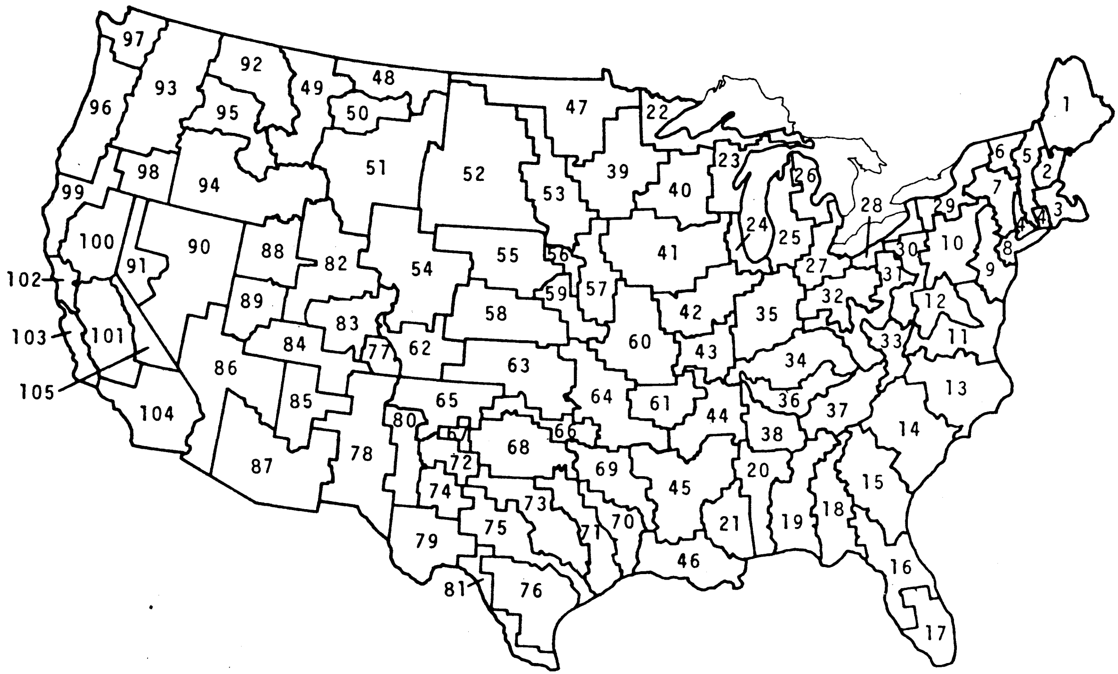

Figure 2. The 105 producing areas

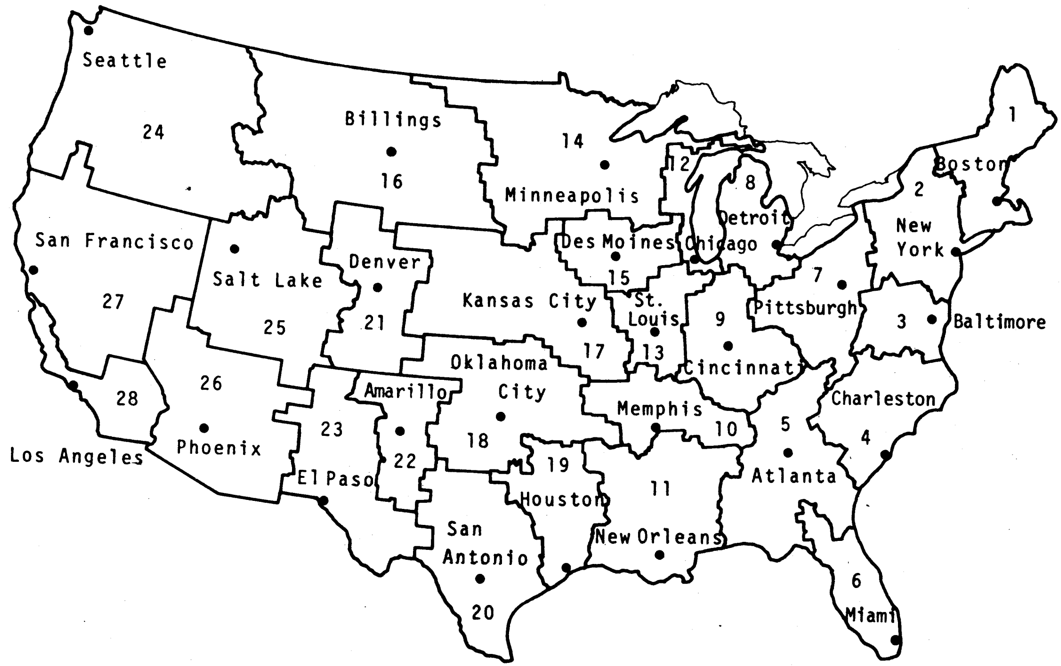

Figure 3. The 28 market regions

and transportation center. The metropolitan centers identified in each market region link the model's transportation sector.

The reporting regions shown in Figure 4 also are formed by aggregating contiguous producing areas.

Land Base

The model's land base was built from the Conservation Needs Inventory, which reports acres of land by use and by agricultural capability class [3]. The CNI uses eight major capability classes with classes II through VIII further subdivided to reflect the most severe hazard which prevents the land from being available for unrestricted use. The subclasses reflect susceptibility to erosion (e), subsoil erosion (s), drainage problems (w), and climate conditions preventing normal crop production (c) [3].

The county acreages are aggregated, for dryland and irrigated uses, to the 105 producing regions by the 29 capability class-subclasses. These 29 class-subclasses are then aggregated to give the five land quality classes shown in Table 1 to serve as the land base in the model.

Table 1. Land class and subclass aggregations to the five land quality classes

Land Quality Class	Inventory Class-Subclasses	Acres
1	I, IIwa[a], IIIwa	64,596,000
2	rest of II, III, IV, all of V	213,385,000
3	IIIe	71,001,000
4	IVe	29,886,000
5	VI, VII, VIII	14,340,000

[a]wa means that the drainage problem has been eliminated.

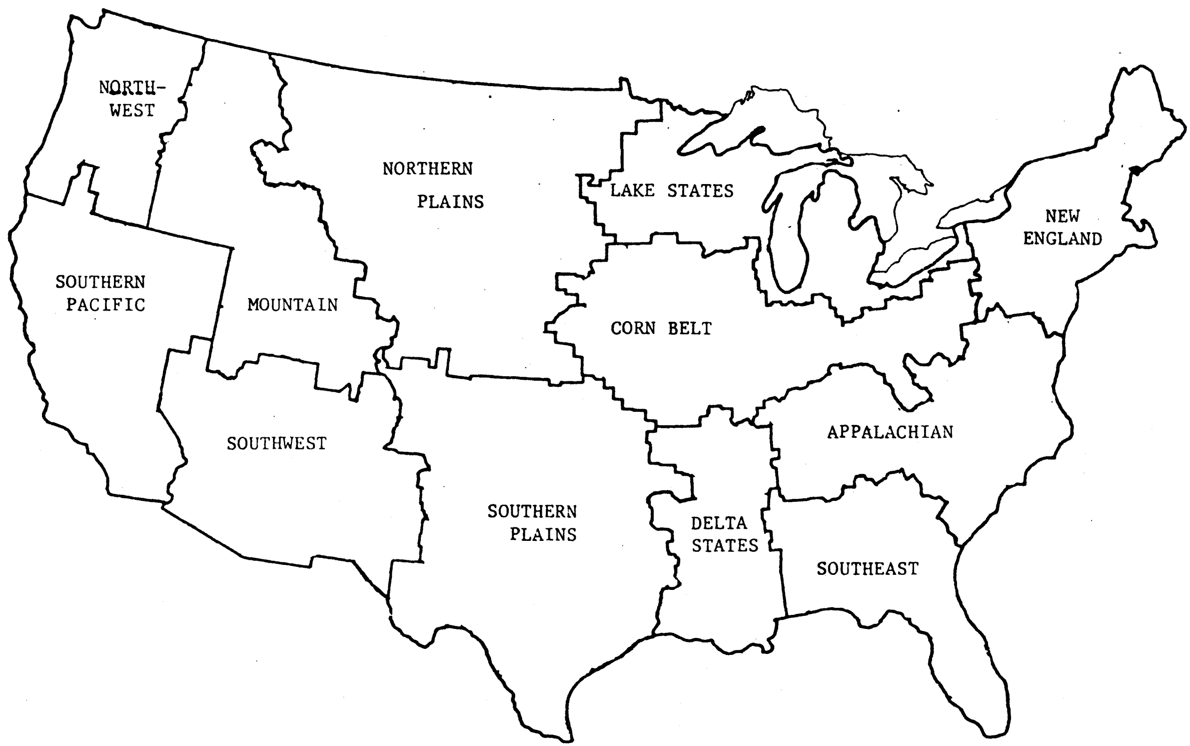

Figure 4. The 12 reporting regions

Additional information concerning the development of the land base, including adjustments to update the National Inventory data, can be found in Meister and Nicol [8].

Crop Production Sector

The endogenous crop production sector is defined on the land base and includes alternative production activities for grain sorghum, sorghum silage, barley, corn, corn silage, cotton, legume and nonlegume hay, oats, soybeans, sugar beets, and wheat consistent with the production possibilities of each region. Other crops are considered in the model on an exogenous basis. Unique activities are defined for each land class of the five quality classes in each producing area and specify alternative rotations, tillage and conservation practices, and irrigated or dryland farming. Each combination of these different components represents a crop management system. Using the nitrogen, land, and water resources defined in the model, each system produces commodities needed for livestock and consumer demands.

The procedure used to generate coefficients for crop rotations allows for interrelationships among crops. For example, following legume crops, nitrogen can be carried over to subsequent crops. Each rotation is combined with any one of four conservation practices: straight row cropping, contouring, strip cropping, or terracing. Conservation practices are defined on the land quality classes according to recommendations given in the SCS Questionnaire [8]. A crop management system is completed by adding one of three tillage practices: conventional tillage with residue removed, conventional tillage with residue left, or reduced tillage. These crop management systems then become activities in the crop production sector when they are adjusted to account for producing region differences in production cost, fertilizer requirements, crop yields, water needs, and susceptibility to soil erosion. Further details can be found in Meister and Nicol [8].

Livestock

The livestock sector includes dairy, hogs, beef cows, beef feeding, broilers, turkeys, eggs, sheep and lambs, and a general category for other animals such as horses, mules, ducks, geese, and zoo animals. Livestock production activities are defined only for the endogenous livestock enterprices: hogs, beef cows, beef feeding, and dairying. Coefficients for feed requirements and manure production are required for all categories, but cost data are needed only for the endogenous livestock.

Livestock rations are formulated to allow substitution between grains, between roughages and grains, and between roughages. Hence, the model selects least-cost rations for the livestock in each region. The nitrogen in the manure produced by the livestock sector is transferred to the crop production sector where it is utilized as a fertilizer. Detailed discussion of the development of these activities, including specification of the alternative rations and the nutrient value of the animal manure can be found in Meister and Nicol [8].

Water Sector

The water sector of the model defines water availability in the Western United States in producing regions 48-105. The water sector also defines activities for the transfer of water between the producing regions. Additional information about the water supplies and the transfer activities can be found in Colette [2].

Transportation

The transportation routes, defined between all contiguous market regions, are measured by the distance between the metropolitan centers in each market region. Some heavily used long-haul routes between noncontiguous regions also are defined if they reduce mileage by 10 percent over accumulated short-travel routes. Over each route, two activities are defined for each commodity, one for shipment in each direction [8].

Commodity Demands

The demand sector requires the production of the endogenous commodities to meet projected levels of demand for food and fiber, net exports, exogenous livestock feed requirements, and the industrial and nonfood uses [8]. The demands are based on the OBERS 1985 projections [12, 13]. The demands are defined at the metropolitan centers in each market region. Additional details can be found in Meister and Nicol [8].

Time Horizon

Evaluation of policy impact alternatives within the limitations of the model requires that a sufficient time horizon be specified to allow for the implied adjustments to materialize. In this report, 1985 was selected as the year of analysis. Alternatives defined in the models are designed to be consistent with projected and expected production alternatives available in 1985.

IV. BASE ALTERNATIVE

The solution from the Base Alternative is obtained under the assumption that no environmental restrictions are imposed on agricultural production practices in 1985. The model selects the least-cost way of producing crops without regard for any adverse effects on soil conservation and environmental quality.

Crop Production Patterns

Output of individual crops in the Base Alternative is allocated to areas which have a comparative advantage in their production (Table 2). For example, about 75 percent of the corn and sorghum is produced in the Lake States and the Corn Belt. Over 50 percent of the soybean production is concentrated in the Corn Belt. Together the Northern and Southern Plains raise more than 50 percent of the small grains.

In the model the utilization of the available cropland in each region varies from a low of 67 percent in the Northern Plains to a high of 96 percent in the Southeast region (Table 3). For the United States as a whole, 82 percent of the available land in the Base Alternative is cropped.

Table 2. Regional production by crop in each reporting region in the Base Alternative (1,000 units)

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	351,274	119,070			8,548	9,270
Appalachian	229,690	266,050	123,006	194	12,236	8,106
Southeast		37,185	119,093	2,143	11,221	
Lake States	1,947,183	132,345	140,308		22,152	3,022
Corn Belt	2,666,384	199,190	724,283		27,077	67,200
Delta States	100,356	16,012	164,218	5,728	11,434	16,095
Northern Plains	150,165	1,198,321	17,566		49,774	70,172
Southern Plains	531,587	369,158	33,461	1,093	94,782	199,356
Mountain	14,774	167,424	36		8,056	3,412
Southwest		16,584	1,426	468	8,761	13,928
Northwest	82,901	114,089	17		3,323	8,261
Pacific	19,007	100,886	3,894	1,283	13,157	12,514
United States	6,093,327	2,797,239	1,327,311	10,911	270,532	411,341

Table 3. Percentage of available land in the Base Alternative that is cropped

Regions	Percentage of utilization	Regions	Percentage of utilization
New England	95	Northern Plains	67
Appalachian	76	Southern Plains	81
Southeast	96	Mountain	81
Lake States	94	Southwest	86
Corn Belt	89	Northwest	76
Delta States	86	Pacific	77
		United States	82

Livestock Production Patterns

The regional distribution of livestock production in the Base Alternative is determined simultaneously with regional crop production patterns (Table 4). For example, because corn is an important part of the hog ration and the Lake States and Corn Belt produce about 75 percent of the corn in the base model, 80 percent of the hogs are raised in these two regions. As another example, the beef cattle industry is concentrated in the Corn Belt, the Northern Plains, and the Southern Plains. These three regions contain 75 percent of the beef cattle and produce more than 60 percent of the hay and 80 percent of the silage in the Base Alternative.

The crops produced in the model are used to meet domestic and foreign demands and the feed requirements of the livestock industry. The feed consumption by livestock in the Base Alternative is shown in Table 5. Almost 75 percent of the corn and sorghum is fed to livestock. Only 30 percent and 50 percent respectively of the small grains and oilmeal are consumed by livestock, with the remainder used for food products or exports.

Table 4. Regional distribution of livestock by class in each reporting region in the Base Alternative (1,000 head)

Region	Beef cows	Beef feeding	Dairy	Hogs
New England		786	2,100	
Appalachian	1,032	1,110	1,944	2,615
Southeast	1,017	1,484	1,114	
Lake States	1,185	1,131	1,437	36,716
Corn Belt	6,833	7,097	1,491	54,935
Delta States	2,025	1,179	726	
Northern Plains	11,593	6,657	320	21,551
Southern Plains	24,257	16,502	1,110	
Mountain	1,858	1,326	190	
Southwest	2,308	1,784	161	
Northwest	718	674	189	
Pacific	1,911	1,582	740	

Table 5. Percentage of total output of crops consumed by each livestock class in the Base Alternative

Livestock class	Corn and sorghum grain	Barley, oats and wheat	Oilmeal	Legume and non-legume hay	Corn and sorghum silage
Beef cows	0	1	7	77	43
Beef feeding	5	10	7	5	53
Dairy cows	20	9	6	14	3
Hogs	27	10	11	1	0
Total (including exogenous live-stock)	72	38	54	100	100

Agricultural Inputs

The use of inputs in the Base Alternative varies considerably by crop (Table 6). Corn production uses about 20 percent of the cropland but requires 50 percent of all the nitrogen fertilizer. Pesticides are not needed in equal amounts on all crops but instead are used primarily to protect corn, soybeans, and cotton.

Table 6. Percentage of inputs used in the Base Alternative allocated to the commodity groups[a]

Commodity group	Cropland	Nitrogen	Pesticide expenditures
Corn and sorghum grain	19	45	34
Barley, oats, and wheat	20	19	6
Cotton	2	4	15
Soybeans	25	2	36
Legume and non-legume hay	8	6	1
Corn and sorghum silage	9	13	7

[a]Percentages do not sum to 100 because the table does not include all the crops in the model.

Soil Erosion

Because of differences in soil type and climate, the land in some of the reporting regions is more susceptible to erosion than others. These differences and the selection of crops and cropping practices for each region determine the rate of soil erosion. The average national rate of soil loss in the Base Alternative, including land in which erosion is nonexistent or is not a hazard, is 4.97 tons per acre, but the rates for individual regions range from a low of less than one ton in the Pacific and Southwest regions to a high of 11 tons per year in the Southeast region (Table 7).

Table 7. Average rates of soil erosion per acre per year for each reporting region in the Base Alternative

Region	Soil loss/acre (tons)	Region	Soil loss/acre (tons)
New England	5.9	Northern Plains	1.1
Appalachian	5.5	Southern Plains	3.7
Southeast	11.0	Mountain	4.6
Lake States	3.3	Southwest	.9
Corn Belt	8.8	Northwest	1.9
Delta States	5.2	Pacific	.8
		United States	5.0

V. SOIL CONSERVATION ALTERNATIVE

The Base Alternative was formulated so that no restrictions were placed on the selection of cropping practices, regardless of their effect on soil erosion. The Soil Conservation Alternative is formulated so that soil erosion rates will be less than the soil loss tolerance rates set by soil scientists as necessary if the productivity of the land is to be maintained in the future (see page 7).

The cropping activities in both alternatives are defined by land quality class in each producing area and specify a combination of rotation, tillage, and conservation practices (see page 17). The rate of soil erosion for each of these cropping activities is determined with the Universal Soil Loss Equation (see page 7). To develop the Soil Conservation Alternative, each cropping activity in the Base Alternative is checked and only those activities with erosion rates less than the soil loss tolerance levels are allowed in the Soil Conservation Alternative.

Changes in the Crop Production Practices

The effects of limiting the options in cropping practices in the Soil Conservation Alternative to those restricting per acre soil losses to the specified levels are shown in Tables 8, 9, and 10.[1] The proportion of acres protected with reduced tillage increases under the Soil Conservation Alternative. There also is less continuous row cropping, and the use of strip cropping and terracing increases.

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[1]In Table 9, the numbers 25, 50, 75, and 100 represent rotations which have these percentages of the land devoted to row crops. Thus, under the Base Alternative 18 percent of the land is in a rotation which has 25 percent of the land in row crops.

Table 8. Comparison of the percentage of acres by conservation practice in the Base Alternative and the Soil Conservation Alternative

Conservation practices	Base Alternative	Soil Conservation Alternative
Straight row and contour farming	92	78
Strip cropping and terracing	8	22

Table 9. Comparison of percentage distribution of row crop acres by rotation in the Base Alternative and the Soil Conservation Alternative

Model	Percent of rotation sequence that is row cropping 25	50	75	100
Base Alternative	18	29	11	41
Soil Conservation Alternative	33	27	15	22

Table 10. Comparison of the percentage of acres by tillage practice in the Base Alternative and the Soil Conservation Alternative

Tillage practice	Base Alternative	Soil Conservation Alternative
Conventional tillage with residue removed	15	12
Conventional tillage with residue left	25	21
Reduced tillage	60	67

Crops, such as corn and soybeans, that do not provide adequate protection for the soil can be grown in rotations with small grain and hay crops which do protect the soil. Or, they can be grown using conservation practices such as strip cropping and terracing. The result of such changes is to increase the relative cost of production for row crops relative to small grains and hay. A consequence of this shift in relative profitability is a 30 percent decline in the acreage of silage and increases of 34 and 33 percent respectively in the acreage of small grains and hay in the Soil Conservation Alternative compared to the Base Alternative (Table 11).

Table 11. Percentage change of output and inputs by commodity group in the Soil Conservation Alternative compared to the Base Alternative

Commodity group	Production	Acres	Nitrogen	Pesticide expenditures
Corn and sorghum grain	-3	4	5	2
Barley, oats, and wheat	32	34	48	67
Cotton	0	-3	22	0
Soybeans	-6	-4	113	8
Legume and non-legume hay	15	33	48	262
Corn and sorghum silage	-35	-31	-28	-30

One effect of the relative changes in the production of crops in the Soil Conservation Alternative compared to the Base Alternative is a substitution of small grains and hay for silage in the livestock rations (Table 12).

Table 12. Comparison of percentage distribution of feedstuffs by weight consumed by all classes of livestock in the Base Alternative and the Soil Conservation Alternative

Commodity group	Base Alternative	Soil Conservation Alternative
Corn and sorghum grain	11	11
Barley, oats, and wheat	2	6
Oilmeals	3	2
Legume and non-legume hay	33	43
Corn and sorghum silage	51	37

Changes in Regional Crop Production Patterns

The changes in cropping practices required by the Soil Conservation Alternative, as compared to the Base Alternative, cause some reorganization of regional crop production patterns (Table 13). Small grain production increases substantially in the Corn Belt and the Delta States regions offsetting the declining production of the row crops: corn, sorghum, and soybeans. This substitution of crops in the Corn Belt and the Delta States is needed because of the erosion problems caused by row cropping in these regions.

The smaller erosion problems of the Northern Plains greatly favors the production of corn, sorghum, and soybeans in this region under the Soil Conservation Alternative. For the same reason, cotton production shifts from the Appalachian and Southeast regions to the West, especially to the Pacific region.

Table 13a. Changes in regional production by crop in each reporting region between the Soil Conservation Alternative and the Base Alternative (1,000 units)

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-52,701[a]	-23,388	5,813	0	845	-2,253
Appalachian	76,591	-32,503	12,250	-194	7,266	-5,738
Southeast	105,136	-6,390	-88,298	-1,734	2,654	2,115
Lake States	-12,972	25,064	20,669	0	-2,586	-972
Corn Belt	-428,347	601,824	-158,406	0	20,535	-53,786
Delta States	-87,921	226,614	-54,386	429	-1,019	-9,360
Northern Plains	229,327	97,434	141,455	0	2,908	-9,716
Southern Plains	-14,014	24,416	36,177	294	9,171	-66,274
Mountain	39,947	-13,038	17	0	2,536	3,007
Southwest	10,447	-5,771	154	50	603	-550
Northwest	-69,938	62,644	7	0	-257	-268
Pacific	4,135	-25,594	3,463	1,155	-458	-1,787
United States	-198,309	899,655	-81,082	0	41,482	-145,582

[a]Positive values indicate an increase in production of the crop in the Soil Conservation Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 13b. Percentage changes in regional production by crop in each reporting region between the Soil Conservation Alternative and the Base Alternative

Region	Corn and sorghum grain (bu.)	Barley oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-15[a]	-20	---	0	10	-24
Appalachian	33	-12	10	-100	59	-71
Southeast	---	-17	-74	-81	24	---
Lake States	-1	19	15	0	-12	-32
Corn Belt	-16	302	-22	0	76	-80
Delta States	-88	1,415	-33	7	-9	-58
Northern Plains	153	8	805	0	6	-14
Southern Plains	-3	7	108	27	10	-33
Mountain	270	-8	47	0	31	88
Southwest	---	-35	10	11	7	-4
Northwest	-84	55	41	0	-8	-3
Pacific	-22	-25	89	90	-3	-14
United States	-3	32	-6	0	15	-35

[a]Positive values indicate an increase in production of the crop in the Soil Conservation Alternative compared to the Base Alternative. Negative values have the opposite meaning.

The shifts in crop production shown in Table 13 and the changes in the soil management practices shown in Tables 8, 9, and 10 result in substantial decreases in the rates of soil erosion (Table 14). The Southeast and the Corn Belt regions are affected most because of their high rates of erosion due to greater rainfall and more sloping land.

Table 14. Comparison of average rates of soil erosion by reporting region in the Base Alternative and the Soil Conservation Alternative

Region	Annual soil loss per acre (tons)	
	Base Alternative	Soil Conservation Alternative
New England	5.9	2.0
Appalachian	5.5	2.2
Southeast	11.0	2.5
Lake States	3.3	2.2
Corn Belt	8.8	2.7
Delta States	5.2	3.1
Northern Plains	1.1	1.3
Southern Plains	3.7	2.1
Mountain	4.6	2.1
Southwest	.9	1.0
Northwest	1.9	1.5
Pacific	.8	.7
United States	5.0	2.1

Changes in Regional Livestock Production

The changes in crop production practices and patterns affect the regional distribution of the livestock industry in the Soil Conservation Alternative as compared to the Base Alternative (Table 15). Beef cattle are substituted for hogs in the Corn Belt as corn production declines and hay production increases because of the erosion hazards associated with row cropping. Most of the displaced hogs shift to the Northern Plains, which increases corn production under the Soil Conservation Alternative since it has fewer erosion problems. Hog production expands in the Northern Plains at the expense of beef cattle. In the Appalachian region one type of livestock production does not replace another in the shift from the Base Alternative to the Soil Conservation Alternative.

Table 15. Changes in the regional distribution of livestock in each reporting region between the Soil Conservation Alternative and the Base Alternative (1,000 head animal numbers and percentages)

Region	Beef cows	% change	Beef feeding	% change	Dairying	% change	Hogs	% change
New England	0	0	-1	.1	-1	0	0	0
Appalachian	777[a]	75	469	42	0	0	3,690	141
Southeast	-153	-15	499	34	0	0	0	0
Lake States	-496	-42	-107	-9	0	0	-1,135	-3
Corn Belt	1,715	25	665	9	0	0	-13,615	-25
Delta States	215	11	-577	-49	0	0	0	0
Northern Plains	-1,462	-13	-594	-9	0	0	11,062	51
Southern Plains	-653	-3	-334	-2	-25	-2	0	0
Mountain	263	14	175	13	0	0	0	0
Southwest	-244	-11	-88	-5	12	7	0	0
Northwest	111	15	96	14	0	0	0	0
Pacific	-58	-3	-215	-14	0	0	0	0

[a]Positive values indicate an increase in animal numbers in the Soil Conservation Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Changes in Resource Use

Changes in crop production practices and patterns under the Soil Conservation Alternative result in changes in the utilization of the available cropland in the reporting regions (Table 16). Acres under cultivation increase significantly in the Northern Plains and the Appalachian regions but decline considerably in the Southeast in the Soil Conservation Alternative as compared to the Base Alternative. This decline in the Southeast accounts for part of the large decrease in the rate of soil erosion in this region as highly erosive land is shifted out of crops in the Soil Conservation Alternative (Table 14).

Table 16. Comparison of the percentage of available cropland that is planted to crops in the Base Alternative and the Soil Conservation Alternative

Region	Base Alternative	Soil Conservation Alternative
New England	95	85
Appalachian	76	84
Southeast	96	70
Lake States	94	96
Corn Belt	89	89
Delta States	86	85
Northern Plains	67	83
Southern Plains	81	83
Mountain	81	82
Southwest	86	87
Northwest	76	81
Pacific	77	77
United States	82	86

Restrictions on the use of the land alter input-use relationships in the Soil Conservation Alternative relative to the Base Alternative. In total, the Soil Conservation Alternative requires about 15 million additional acres, 14 percent more nitrogen, and a 7 percent increase in pesticide expenditures as compared to the Base Alternative. The data in Table 11 show the changes in input use for the various commodity groups. Yields change with the regional shifts in crop production. For example, the acres allocated to corn and sorghum production increase by 4 percent in the Soil Conservation Alternative compared to the Base Alternative but total production declines by 3 percent because of lower yields as some corn and sorghum production shifts from the Corn Belt to the less productive lands of the Northern Plains in the Soil Conservation Alternative. The additional acres raise the requirements for nitrogen and pesticides.

Supply Prices

The expansion of crop production to the less productive lands and the use of more costly practices to control soil erosion raises the supply prices for the commodities in the Soil Conservation Alternative (Table 17).[1] Soybeans were especially affected by the soil conservation

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[1]The supply price for a commodity is defined as that price which brings forth the quantity of output needed to meet demands under the given conditions. The programming model selects the production cost of the last land class in the last producing area contributing towards total supply as the supply price. Because of the perfect competitive framework in which this model is formulated, the last producing area to enter would be the highest cost area. Returns imputed to land, then, are the difference between supply price and production cost of the cropping activity selected by the model by land quality class in each producing area.

restraint. Their supply price is 43 percent greater under the Soil Conservation Alternative than under the Base Alternative. The supply price of wheat production declines by 3 percent as it shifts some to the more productive lands of the Midwest. Supply prices for the livestock products increase because of the higher prices for the feedstuffs in their rations.

Table 17. Percentage change in the supply prices for the commodities in the Soil Conservation Alternative compared to the Base Alternative

Commodities	Percent change	Commodities	Percent change
Crops		Nonlegume hay	3
Corn	7	Silage	3
Sorghum	1	Cotton	9
Barley	3	Livestock Products	
Oats	12	Milk	2
Wheat	-3	Pork	7
Oilmeal	43	Beef	5
Legume hay	5		

Regional Changes in the Value of Production

Implementation of a national soil conservation program to reduce soil erosion is being discussed by legislators. Policies of this type, as represented in the Soil Conservation Alternative, can have important effects by causing an interregional redistribution of the nation's agricultural income. This possibility is reflected in the results of our analysis.

The total value of agricultural production increases substantially in three of the reporting regions in the Soil Conservation Alternative compared to the Base Alternative (Table 18). Increases in the production of corn and soybeans and the expansion of hog and cattle production produce large increases in the value of production in the Appalachian region. The value of production in the Northern Plains region also increases as a result of increased soybean acreage and hog numbers. In the Mountain region, the increase in the total value of agricultural production is due to increased corn production and the expansion of the beef cattle industry. The value of production declines slightly in three regions as they lose crops to other regions.

Table 18. Percentage changes in the regional value of agricultural production in the Soil Conservation Alternative relative to the Base Alternative

Region	Percentage change	Region	Percentage change
New England	-4	Northern Plains	20
Appalachian	28	Southern Plains	4
Southeast	-3	Mountain	19
Lake States	7	Southwest	2
Corn Belt	8	Northwest	7
Delta States	-1	Pacific	3

Implications for Farmers

The changes in farming practices indicated by the analysis will require new management skills and more capital investments by farmers.

Shifting from conventional tillage to reduced tillage also creates new weed and insect problems and constructing terraces requires substantial capital investments in the land.

The results from the analysis also imply capital gains and losses for current landowners. As a national average, the value of land subject to excessive erosion falls because of both the additional expense of controlling soil erosion and shifts to less intensive cropping systems. The shadow price of land not subject to erosion rises. The value of land least susceptible to erosion (Class 1) increases by 32 percent in the Soil Conservation Alternative compared to the Base Alternative.[1] The land most susceptible to erosion (Class 4) declines in value by 3 percent as a national average.

Percentage changes in the value of land from the analysis (Table 19) have important implication in regional redistribution of asset values. Table 20 shows percentage change in actual land prices by state from 1967 to 1976. These historical data show that farmland in the Northeastern states has had a large increase in value relative to the rest of the country. However, comparison of the value of cropland in the Soil Conservation Alternative with the Base Alternative shows a decline of 5 percent for the New England region, thus implying that the high rate of increase in land values will be slowed by a soil conservation policy paralleling the Soil Conservation Alternative. The results indicate a large negative impact in the Southwest region (the value of land declines 43 percent). Historically, land values have

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[1]See page 18 for definition of land classes.

increased slowly in the Southern Plains, and the analysis implies that imposing a national soil conservation restraint could cut back land values in this region. Reduced land values also would occur in the Southern Plains and the Northwest regions.

Table 19. Percentage changes in the regional shadow prices of land in the Soil Conservation Alternative relative to the Base Alternative

Region	Percentage change	Region	Percentage change
New England	-5	Northern Plains	25
Appalachian	109	Southern Plains	-6
Southeast	-43	Mountain	24
Lake States	71	Southwest	17
Corn Belt	35	Northwest	-10
Delta States	57	Pacific	27

Regions with an increase in land value under the Soil Conservation Alternative are those which gain in crop acreage and intensity of row cropping due to soil and climatic conditions less conducive to soil erosion. The greatest increases are in the Appalachian, Lake States, Corn Belt, and Delta States. Increases also occur in the Northern Plains, Mountain, and Pacific regions. These statements refer to overall averages for the regions. Of course, differential changes also would occur among producing areas (Figure 2) within the reporting regions (Figure 3).

Table 20. Percentage changes in land values by state from March 1967 to November 1976 [16]

State	Percent change	State	Percent change
Northeast		Delta States	
New England	193	Mississippi	105
New York	204	Arkansas	129
New Jersey	277	Louisiana	115
Pennsylvania	291	Northern Plains	
Delaware	222	North Dakota	232
Maryland	213	South Dakota	168
Appalachian		Nebraska	203
Virginia	180	Kansas	157
West Virginia	317	Southern Plains	
North Carolina	134	Oklahoma	146
Kentucky	153	Texas	127
Tennessee	174	Mountain	
Southeast		Montana	198
South Carolina	193	Idaho	195
Georgia	206	Wyoming	170
Florida	142	Colorado	170
Alabama	167	Utah	171
Lake States		Nevada	207
Michigan	132	Southwest	
Wisconsin	204	New Mexico	118
Minnesota	228	Arizona	123
Corn Belt		Northwest	
Ohio	202	Washington	126
Indiana	195	Oregon	150
Illinois	228	Pacific	
Iowa	256	California	60
Missouri	162		

VI. NITROGEN RESTRICTION ALTERNATIVE

The formulation of the Base Alternative allows agriculture to use the quantity of nitrogen needed to maximize farmers' profits. Under this condition additional nitrogen can be applied on crops until the value of the resulting yield increases is equal to the purchase price of the nitrogen [10]. The Nitrogen Restriction Alternative restrains nitrogen use to a maximum of 50 pounds per acre, an arbitrary amount about half as large as nitrogen usage in the early 1970s. Hence, yields decline for crops using more than 50 pounds per acre in the Base Alternative. These yield changes are the difference between the specification of the two alternatives. The yield changes are predicted on the basis of Spillman production functions estimated for each crop and producing area [7].

Resource Use

With nitrogen use limited in the Nitrogen Restriction Alternative as compared to the Base Alternative, other inputs are substituted so that agriculture continues to meet the given food and fiber demands (Table 21). For example, the restriction on nitrogen use reduces the total application of nitrogen on cotton by 56 percent as compared to the Base Alternative. This reduction lowers average cotton yields by 25 percent. Because of the reduced yields, agriculture is forced to substitute more land (28 percent) and higher pesticide expenditures (35 percent) to maintain production of cotton at levels consistent with the demand levels used in both alternatives.

The differential changes in crop yields (Table 22) created by the nitrogen restriction alters the relative profitability of producing the

Table 21. Percentage change of output and inputs by commodity group in the Nitrogen Restriction Alternative compared to the Base Alternative

Commodity groups	Production	Acres	Nitrogen	Pesticide expenditures
Corn and sorghum	-4	14	-47	7
Barley, oats, and wheat	8	12	-3	26
Cotton	0	28	-56	35
Soybeans	-1	-1	54	-1
Legume and non-legume hay	6	16	-44	22
Corn and sorghum silage	-6	2	-23	-2

various crops. The result is a different mix of crops in the Nitrogen Restriction Alternative (Table 21) than in the Base Alternative. The production of corn and sorghum declines while the output of small grains and hay increases. Because of differences in input requirements for these crops, total resource use in agriculture also changes.

For agriculture as a whole, the limit on the use of nitrogen forces 25 million additional acres into crop production and raises total pesticide expenditures by 8 percent. These changes compensate for a 25 percent reduction in the use of nitrogen. The 25 million acres represent small increases in each of the reporting regions (Table 23), with the exception of the Northern Plains region. The Northern Plains region increases its use of available cropland by a large amount in the Nitrogen Restriction Alternative.

Table 22. Comparison of average crop yields in the Base Alternative and the Nitrogen Restriction Alternative

Crops	Average crop yields per acre	
	Base Alternative	Nitrogen Restriction Alternative
Corn grain (bu.)	107.4	91.9
Sorghum grain (bu.)	59.2	50.6
Barley (bu.)	57.9	53.5
Oats (bu.)	67.6	64.5
Wheat (bu.)	37.1	35.7
Corn silage (ton)	16.4	13.7
Sorghum silage (ton)	14.4	13.6
Legume hay (ton)	4.1	4.1
Nonlegume hay (ton)	2.3	2.1
Soybeans (bu.)	34.0	33.7
Cotton (bales)	1.6	1.2

Regional Changes in Crop and Livestock Production

Data in Table 24 may seem to imply large regional shifts in crop production patterns. However, further examination of the data indicates that the changes generally are modest. For example, in the Corn Belt, total production of corn and sorghum declines. However, total acres planted to these crops actually increases under the Nitrogen Restriction Alternative as compared to the Base Alternative. The decline in production is due to yield decreases. The increased production of small grains in the Corn Belt is due to a greater acreage of barley, oats, and wheat. The greater acreage of small grains is part of the 6 percent increase in cultivated land in the Corn Belt (Table 23). Small grains,

Table 23. Comparison of the percentage of available cropland that is planted to crops in the Base Alternative and the Nitrogen Restriction Alternative

Region	Base Alternative	Nitrogen Restriction Alternative
New England	95	99
Appalachian	76	78
Southeast	96	96
Lake States	94	95
Corn Belt	89	95
Delta States	86	90
Northern Plains	67	82
Southern Plains	81	84
Mountain	81	87
Southwest	86	85
Northwest	76	82
Pacific	77	79
United States	82	88

rather than corn, are grown on these acres because of the decreased profitability of corn when its yields are reduced by the limit on nitrogen use.

Some large interregional shifts in livestock production accompany the change in cropping patterns (Table 25). For example, the increased production of hay and silage and the reduced output of corn in the Corn Belt causes a substitution of beef cattle for hogs. A similar shift of crop and livestock production occurs in the Appalachian region. Hogs displaced from the Corn Belt and the Appalachian regions shift to the Lake States and the Northern Plains.

Table 24a. Changes in regional production by crop in each reporting region between the Nitrogen Restriction Alternative and the Base Alternative (1,000 units)[a]

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (Bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-54,653	42,715	0	0	87	-5,789
Appalachian	-16,792	20,238	-31,800	762	3,576	2,443
Southeast	0	14,663	-18,038	770	14	0
Lake States	-245,281	16,520	737	0	-25	445
Corn Belt	-273,842	29,255	-953	0	1,452	5,524
Delta States	-84,673	12,758	9,228	-961	1,208	1,203
Northern Plains	71,054	166,727	29,501	0	9,353	-10,287
Southern Plains	52,090	-30,177	-2,170	485	-1,229	-9,693
Mountain	14,798	-3,412	53	0	1,978	-3,412
Southwest	12,396	12,636	662	227	-1,977	-7,863
Northwest	-15,543	12,051	52	0	24	-335
Pacific	30,811	-18,262	-3,839	-1,283	2,700	2,287
United States	-239,634	214,164	-16,563	0	17,160	-26,199

[a]Positive values indicate an increase in production of the crop in the Nitrogen Restriction Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 24b. Percentage changes in regional production by crop in each reporting region between the Nitrogen Restriction Alternative and the Base Alternative

Region	Corn and sorghum grain (bu.)	Barley oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-16[a]	36	0	0	1	-60
Appalachian	-7	8	-26	393	29	30
Southeast	0	39	-15	36	.1	0
Lake States	-13	12	.5	0	.1	15
Corn Belt	-10	15	-.1	0	5	8
Delta States	-84	80	0	-17	11	7
Northern Plains	47	14	168	0	19	-15
Southern Plains	10	-8	-6	44	-.1	-5
Mountain	100	-2	147	0	24	-100
Southwest	---	76	46	48	-23	-56
Northwest	-19	11	306	0	.7	-4
Pacific	162	-18	-99	-100	20	18
United States	-4	8	-1	0	6	-6

[a]Positive values indicate an increase in production of the crop in the Nitrogen Restriction Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 25. Changes and percentage changes in the regional distribution of livestock by class in each reporting region between the Nitrogen Restriction Alternative and the Base Alternative (1,000 head animal numbers and percentages)[a]

Region	Beef cows	% change	Beef feeding	% change	Dairying	% change	Hogs	% change
New England	0	0	-557	-71	-151	7	0	0
Appalachian	626	61	351	32	-6	.3	-2,615	-100
Southeast	100	10	122	8	0	0	0	0
Lake States	-207	-17	173	15	154	11	9,573	26
Corn Belt	678	10	687	10	-2	.1	-21,459	-39
Delta States	227	11	86	7	0	0	0	0
Northern Plains	-77	-1	42	1	0	0	14,503	67
Southern Plains	-997	-4	-495	-3	-24	-2	0	0
Mountain	51	3	13	1	0	0	0	0
Southwest	-1,026	-44	-854	-48	13	8	0	0
Northwest	115	16	100	15	0	0	0	0
Pacific	476	25	327	21	0	0	0	0

[a]Positive values indicate an increase in animal numbers in the Nitrogen Restriction Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Besides the regional shifts, the changes in the relative mix of commodities result in a substitution of small grains and hay for silage in the livestock rations in the Nitrogen Restriction Alternative as compared to the Base Alternative (Table 26).

Soil Erosion

Soil erosion is increased when agriculture is forced to bring additional land into production as a substitute for nitrogen and restraints are not placed on soil loss. Nationally, total soil erosion

Table 26. Comparison of percentage distribution of feedstuffs consumed by all classes of livestock in the Base Alternative and the Nitrogen Restriction Alternative

Commodity	Percentage distribution by weight: Base Alternative	Percentage distribution by weight: Nitrogen Restriction Alternative
Corn and sorghum grain	10	10
Barley, oats, and wheat	2	3
Oilmeals	3	2
Legume and non-legume hay	33	35
Corn and sorghum silage	51	49

is 14 percent higher in the Nitrogen Restriction Alternative than in the Base Alternative. The greater loss of soil is due to higher erosion rates (Table 27) as well as to the additional acres planted to crops. Erosion rates increase because land less suitable for cultivation is forced into production and the average rate of soil erosion is raised.

Supply Prices

When less productive land is brought into production to compensate for reduced yields, the supply prices for the crops increase (Table 28). These price increases, in turn, raise the supply price of the livestock products in the Nitrogen Restriction Alternative as compared to the Base Alternative.

Regional Changes in the Value of Production

As for the other major structural shifts implied for the nation's agriculture, a forced reduction in fertilizer use for environmental or

Table 27. Comparison of average per acre rates of soil erosion per year by reporting region in the Base Alternative and the Nitrogen Restriction Alternative (tons)

Region	Base Alternative	Nitrogen Restriction Alternative
New England	5.9	5.9
Appalachian	5.5	6.5
Southeast	11.0	11.0
Lake States	3.3	3.3
Corn Belt	8.8	9.4
Delta States	5.2	6.3
Northern Plains	1.1	1.3
Southern Plains	3.7	3.8
Mountain	4.6	4.9
Southwest	.9	1.2
Northwest	1.9	1.9
Pacific	.8	.8
United States	5.0	5.2

Table 28. Percentage increase in the supply prices for commodities in the Nitrogen Restriction Alternative relative to the Base Alternative

Commodities	Percent increase	Commodities	Percent increase
Crops		Nonlegume hay	7
Corn	8	Silage	4
Sorghum	5	Cotton	14
Barley	0	Livestock products	
Oats	0	Milk	4
Wheat	9	Pork	3
Oilmeal	1	Beef	4
Legume hay	1		

other purposes could have important impacts in the interregional distribution of income. This potential exists because some regions, such as irrigated areas, are based heavily on fertilizer use. Other areas which also use high per acre rates of fertilization may offset reduced nitrogen use by a greater total acreage of crops.

The total value of agricultural production changes substantially in three of the reporting regions in the Nitrogen Restriction Alternative, as compared to the Base Alternative (Table 29). The increase in the total

Table 29. Percentage changes in the regional value of agricultural production in the Nitrogen Restriction Alternative relative to the Base Alternative

Regions	Percent change	Regions	Percent change
New England	-6	Northern Plains	19
Appalachian	8	Southern Plains	3
Southeast	7	Mountain	4
Lake States	10	Southwest	-32
Corn Belt	-1	Northwest	8
Delta States	3	Pacific	7

value of production in the Lake States is due to expanded swine production. Increases in the production of hogs, corn, and soybeans account for higher total value of output in the Northern Plains. The drop in the total value of production in the Southwest occurs especially because of the decline in feed production and hence cattle feeding under the Nitrogen Restriction Alternative.

Implications for Individual Farms

For agriculture as a whole, land is substituted for nitrogen to maintain output at the same level as in the Base Alternative. However, an individual farmer would be unable to make this substitution to compensate for lower yields if all of his land were already in crops. The result would be a reduced total production on these individual farms. The possibility of reduced farmer income due to restricted fertilizer use is greatest for farmers producing corn, sorghum, and cotton. In general, their cropland is fully employed in cropping even under the Base Alternative. The Nitrogen Restriction Alternative also implies capital gains for some landowners and losses for others. As per acre production declines and regional crop production patterns are altered, the return imputed to land also changes. These changes in the land returns (Table 30) have implications for regional farmland asset values. As shown in Table 20, increases in land values over the period 1967-76 were largest in the Northwest and the Corn Belt. Results of the current analysis indicate that land values would be further augmented under the Nitrogen Restriction Alternative. The Southwest and the Pacific areas experienced smaller increases in land values over the 1967-76 period. Similarly, these regions would have a land value reduction under the Nitrogen Restriction Alternative.

For the nation as a whole, the supply prices of commodities (Table 28) and the value of agricultural production (Table 29) increase slightly. These increases are due to inelastic commodity demands in a setting of restrained production. The changes in the prices and value of agricultural production would bring gain to farmers as a total group. However, as indicated in Table 29, the gain in some regions would be accompanied by losses in other regions.

Table 30. Percentage changes in the regional shadow prices of land in the Nitrogen Restriction Alternative relative to the Base Alternative

Regions	Percent change	Regions	Percent change
New England	46	Northern Plains	9
Appalachian	18	Southern Plains	8
Southwest	28	Mountain	5
Lake States	24	Southwest	-18
Corn Belt	5	Northwest	8
Delta States	4	Pacific	-15

Consumers, of course, would sacrifice in food costs as is suggested by the price increases indicated in Table 28 and the increased value of agricultural production in Table 28. Consumers would need to compare this cost in increased food prices with the gains represented by reduced nitrogen levels of streams and water bodies. The data of this study do not allow measurements of gains from reduced nitrate levels. However, the increase in commodity supply prices (Table 28) is relatively modest at the farm level. Some additional quantity would be added to food costs as farm commodities move through the processing and retailing stages.

VII. INSECTICIDE RESTRICTION ALTERNATIVE

The potential impact of a ban on the use of Chlordane and Heptachlor is analyzed in this section. The Base Alternative allowed corn producers in the Midwest to use these insecticides to protect their crop from soil insects. The insecticide restriction is formulated by selecting substitutes for Chlordane and Heptachlor and then making appropriate adjustments for cost and yield changes.[1] The substitutes selected are Thimet, Mocap, Dasanit, and Furadan. These materials are more expensive than Chlordane and Heptachlor and equally effective except for two insect problems: (a) the first year insect complex of wireworms and grubs in corn following a grass crop and (b) cutworm damage to corn grown in lowland areas.

To reflect the relative ineffectiveness of the substitutes in the first year insect complex, it is assumed that 20 percent of first year corn suffers a 5 percent yield reduction. The net result is a 1 percent yield reduction on an average acre of first year corn following a grass crop.

The ineffectiveness of the substitutes against cutworms also requires changes in yields and costs. We assume that 15 percent of the lowlands in land quality class 2 (see page 18) will be attacked by cutworms and that 25 percent of these infested acres will have to be replanted. For the other 75 percent of the infested acres we assume that

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[1]The cost and yield adjustments were made with the help of Dr. H. J. Stockdale and Dr. G. R. DeWitt of the Iowa State University Department of Entomology.

(a) three-quarters will receive additional insecticide applications as a rescue treatment but still suffer a 15 percent yield reduction and (b) the other one-quarter will be untreated and suffer a 25 percent yield reduction. These assumptions were formulated on the basis of existing knowledge and the judgment of professional entomologists. Persons wanting to test other possible levels of yield damage could run alternative assumptions through the same model.

Changes in Crop Production Patterns

The increased costs and the lower crop yields for the lowlands due to cutworm damage results in a partial substitution of soybeans and small grains for corn. The proportion of the total acres of corn produced on land quality classes 1 and 3 increases relative to land quality class 2 because of the reduced profitableness of producing corn on class 2 land (Table 31). The acreage of soybeans and small grains has an opposite shift since these crops are substituted for corn on class 2 land (Tables 32 and 33).

Table 31. Corn acreage in the Corn Belt by land class in the Insecticide Restriction Alternative as compared to the Base Alternative

Land class	Base Alternative		Insecticide Restriction Alternative	
	Acres (1,000)	Proportion by land class	Acres (1,000)	Proportion by land class
1	8,053	36	9,596	48
2	10,861	49	6,935	35
3	2,768	12	3,104	16
4	438	2	272	1
Total	22,120		19,907	

Table 32. Soybean acreage in the Corn Belt by land class in the Insecticide Restriction Alternative as compared to the Base Alternative

	Base Alternative		Insecticide Restriction Alternative	
Land class	Acres (1,000)	Proportion by land class	Acres (1,000)	Proportion by land class
1	10,943	26	9,326	21
2	24,286	57	27,539	63
3	6,500	15	6,342	14
4	796	2	788	2
Total	42,525		43,995	

Table 33. Small grain acreage in the Corn Belt by land class in the Insecticide Restriction Alternative as compared to the Base Alternative

	Base Alternative		Insecticide Restriction Alternative	
Land class	Acres (1,000)	Proportion by land class	Acres (1,000)	Proportion by land class
1	563	11	563	11
2	1,762	35	2,146	41
3	1,781	35	1,610	30
4	968	19	965	18
Total	5,074		5,284	

The yield reduction for rotations with first year corn following a grass crop results in a reduction of 75 percent in the acreage of first year corn under the Insecticide Restriction Alternative as compared to the Base Alternative.

Regional Crop and Livestock Production Patterns

Increases in the cost of corn production because of the more costly substitutes to control insect damage creates an economic incentive to shift some corn and hog production away from the Corn Belt. Corn acreage declines by 10 percent while soybean and small grain acreage increase by 3 and 4 percent respectively in the Corn Belt (Tables 31, 32, and 33) under the Insecticide Restriction Alternative as compared to the Base Alternative. Some hog production shifts from the Corn Belt to the Lake States and the Northern Plains (Table 34).

Table 34. Changes in the regional distribution of livestock in each reporting region between the Insecticide Restriction Alternative and the Base Alternative

	Animal numbers (1,000 head)[a]			
Region	Beef cows	Beef feeding	Dairying	Hogs
New England	0	0	0	0
Appalachian	181	-55	0	0
Southeast	1	0	0	0
Lake States	-195	115	0	1,553
Corn Belt	87	-44	0	-3,403
Delta States	-104	-60	0	0
Northern Plains	-207	-63	0	1,851
Southern Plains	179	115	0	0
Mountain	-23	-14	0	0
Southwest	7	0	0	0
Northwest	-16	-14	0	0
Pacific	41	28	0	0

[a]Positive values indicate an increase in animal numbers in the Insecticide Restriction Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Changes in Cost of Production

The substitutes for Chlordane and Heptachlor raise pesticide expenditures by 24 percent in the Corn Belt. However, due to the regional adjustments in corn production and since pesticides are a small percentage of the total costs of production, the supply price of corn increases by only 1 cent in the Insecticide Restriction Alternative compared to the Base Alternative.

Implications for Farmers

The substitution of insecticides for corn has little impact on agriculture other than to put the Midwest at a slight economic disadvantage. However, some individual corn producers still would be adversely affected. Farmers growing corn on lowland fields or following a grass crop would not be able to adequately protect their crop from insects. On average for all farmers, these losses would be small. But because insect damage may range from zero to a total loss, there is the possibility that the incomes of some farmers would be significantly reduced by the ban on Heptachlor and Chlordane.

VIII. FEEDLOT RUNOFF CONTROL ALTERNATIVE

Requiring feedlot operators to control the runoff from their feedlots to prevent the pollution of nearby waterways raises the cost of livestock production. The Feedlot Runoff Control Alternative is analyzed to determine if economic incentives are created by this regulation which then cause regional shifts in livestock production.

To prevent livestock wastes from being washed into surface water requires the construction of runoff control facilities for the feedlot. Control facilities as specified in this analysis include: a diversion dam to route clean water from surrounding areas away from the feedlot, a sediment basin to separate the solids from the runoff for later disposal on the land, and a lagoon to impound the feedlot runoff for disposal by evaporation or irrigation.

Budgets have been developed showing the added expense to livestock producers who are required to construct these facilities [1, 6, 15]. Adjusting these budgets to reflect regional differences in climate, size of livestock enterprises, and the proportion of livestock in feedlots whose runoff may enter a waterway gives the annual cost of production increases shown in Table 35. The annual cost of runoff control by type of livestock is calculated as:

$$C_{ik} = \sum_j RC_{jik} PM_{jik} P_{jik}$$

$j = 1, \ldots, n$ for livestock enterprise sizes
$i = 1, \ldots, 28$ for the market regions
$k = 1,2,3$ for livestock types; beef feed, dairy, and hogs

where

C_{ik} = the annual cost for runoff control for a representative animal of type k in market region i;

RC_{jik} = the annual cost for runoff control for a representative animal of type k in lot size j in market region i [1, 6, 15];

PM_{jik} = the proportion of total animals of type k in market region i marketed from lot size j [11];

P_{jik} = the estimated proportion of feedlots of size j in market region i with animals of type k whose runoff may enter a waterway [1, 6, 15].

These values are added to the nonfeed costs in the Base Alternative to create the Feedlot Runoff Control Alternative (Table 35).

Regional Production of Livestock in the Feedlot Runoff Control Alternative

The differential increases in the cost of production forces some regional adjustment by the livestock industry in the Feedlot Runoff Control Alternative compared to the Base Alternative (Table 36). There are slight shifts of beef cattle from the Lake States to the Corn Belt and from the Northern Plains to the Southern Plains. A small number of hogs shifts from the Corn Belt to the Northern Plains.

Implications for Farmers

Following compliance with the regulation preventing runoff, livestock production costs do not increase significantly in the Feedlot Runoff Control Alternative compared to the Base Alternative. The small cost increase does not mean that all livestock producers are unaffected.

Table 35. Increases in the annual cost of production in dollars per head caused by the feedlot runoff control regulation by consuming region in the Feedlot Runoff Control Alternative

Region	Beef feeding	Dairying	Hogs
1	1.50	5.87	.35
2	1.12	6.75	.57
3	.98	6.73	.55
4	2.37	7.85	.46
5	1.21	7.99	.48
6	.71	4.41	.48
7	1.07	8.37	.50
8	2.11	8.42	.48
9	2.87	10.45	.44
10	2.36	10.08	.52
11	1.04	7.46	.48
12	2.74	8.21	.50
13	2.35	8.83	.44
14	2.52	9.44	.46
15	2.78	9.37	.44
16	1.73	11.80	.33
17	1.75	10.24	.39
18	.76	8.12	.33
19	.28	5.11	.30
20	.21	4.76	.28
21	.70	6.36	.26
22	.24	4.41	.28
23	.15	3.88	.26
24	.68	7.84	.39
25	1.00	7.20	.28
26	.09	4.39	.15
27	.13	4.41	.28
28	.11	4.41	.28

Table 36. Changes in the regional distribution of livestock in each reporting region between the Feedlot Runoff Control Alternative and the Base Alternative (1,000 head)

Region	Beef cows	Beef feeding	Dairying	Hogs
New England	0	1	0	0
Appalachian	-4	-6	0	0
Southeast	0	0	0	0
Lake States	-136	-117	0	1
Corn Belt	86	78	1	-295
Delta States	-14	-9	0	0
Northern Plains	-154	-54	-7	295
Southern Plains	178	114	0	0
Mountain	-5	-4	0	0
Southeast	7	0	0	0
Northwest	-4	-4	0	0
Pacific	10	7	0	0

[a]Positive values indicate an increase in animal numbers in the Feedlot Runoff Control Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Because of the added expense for runoff control facilities, farmers will earn a lower rate of return than expected on their investments. Small operators will be severely affected because the per head cost of runoff control increases sharply with decreasing lot size (Tables 37, 38, and 39).

Table 37. Annual dollar increases in beef feeding cost due to runoff control facilities [6]

Capacity class (head)	Cost increase (per head)
Less than 100	21.17
100 to 199	3.19
200 to 499	1.84
500 to 999	1.26
1,000 and over	.69

Table 38. Annual dollar increases in hog production cost due to runoff control facilities [15]

Capacity class (head sold)	Cost increase (per head)
Less than 100	3.87
100 to 199	1.32
200 to 499	.66
500 to 999	.44
1,000 and over	.27

Table 39. Annual dollar increases in dairy production cost due to runoff control facilities [1]

Herd size	Cost increase (per head)
15	50
30	19
80	10
150	7

IX. EXPORT POTENTIAL ALTERNATIVES

This section includes an analysis of the impact of higher production costs caused by environmental policies on the potential export capacity of U.S. agriculture. Higher production costs decrease the export capacity of agriculture because marginal land, formerly profitable to crop, is taken out of production.

The analysis is conducted using two export alternatives in comparison with the Base Alternative. Both export alternatives are formulated with an export activity allowing the expansion of the production of corn, wheat, oilmeal, and sorghum for export until a weighted average of their supply prices equals a predetermined export price. The four commodities are exported in fixed proportions to prevent specialization in a single export commodity under the alternatives. These proportions are used to weight individual crop supply prices to form an aggregate price.[1] This aggregate supply price rises as exports increase because less productive lands are brought into production. The model does not allow production of commodities which have supply prices greater than their market price. Hence, expansion to new land is limited by the level of export prices.[2]

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[1]The commodities and their respective weights are: corn, .486; oilmeal, .245; wheat, .199; and sorghum, .07.

[2]The export price used is approximately 2.33 times the aggregate shadow price for the commodities in the Base Model.

The first of the two export alternatives, the High Export Alternative, allows production to expand until the aggregate shadow price is equal to an export price and all available cropland is brought into production. This expansion occurs without any controls on the environmental consequences of the increased production activity. The second export alternative, the Restricted Export Alternative, has the same export price but requires that agriculture comply with all four of the environmental policies analyzed earlier. Because each of the environmental policies raises production costs, the effect of the latter is to lower the potential export capacity of agriculture (Table 40). In other words, the Restricted Export Alternative attains the highest level of exports possible when all available cropland is in production and all four environmental policies are in force. These export levels average a third lower than for the High Export Alternative and about 25 percent less than for the Base Alternative.

Table 40. **Comparison of export levels for the Base, High Export, and Restricted Export Alternatives** (1,000 tons)

Commodity	Base Alternative	High Export Alternative	Restricted Export Alternative
Corn	27,692	60,844	37,005
Wheat	23,220	37,764	27,306
Oilmeal	22,562	52,406	30,946
Sorghum	4,480	9,255	5,821

High Export Alternative

Resource use in the High Export Alternative

The High Export Alternative uses 67 million acres more land than does the Base Alternative. However, the expansion of production shown in Table 40 requires more than land (Table 41). For U.S. agriculture as a whole, the High Export Alternative uses 29 percent more nitrogen and increases pesticide expenditures by 50 percent. Most of the nitrogen increase is due to the high requirements of corn and sorghum. The largest proportion of the increase in pesticide expenditures is for corn, sorghum, and soybeans.

Table 41. Quantity and percentage change of output and inputs by commodity groups in the High Export Alternative compared to the Base Alternative

	Commodity Group					
	Corn and sorghum grain	Barley oats, and wheat	Cotton	Soybeans	Legume and non-legume hay	Corn and sorghum silage
Production						
1,000 units	1,509,235	-338,642	104	1,286,140	20,883	5,834
Percent	25	-12	1	46	8	1
Cropland acres						
1,000 acres	18,432	5,810	55	41,327	10,276	3,666
Percent	30	10	1	51	29	14
Nitrogen use						
1,000 tons	1,135	489	-36	303	303	117
Percent	32	32	-11	194	59	11
Pesticide expenditures						
1,000 dollars	177,693	57,665	308,171	254,481	25,631	15,640
Percent	51	95	9	69	515	22

As more cropland is brought into production, crop yields fall because less productive land is used (Table 42). Declines in the yields of barley, oats, and wheat cause output of small grains to decline even though their acreage increases by 10 percent under the High Export Alternative. The yields in column two of Table 42 are depressed from those in column one due alone to the use of a greater land area with lower per acre yields under the high export alternative. However, the lower yields in column three, the Restricted Export Alternative as compared to the Base Alternative, are due to both a greater acreage of marginal lands and reduced use of chemicals under the environmental restrictions.

Table 42. Comparison of average yields in the Base, High Export, and Restricted Export Alternatives

Crops	Average crop yields per acre		
	Base Alternative	High Export Alternative	Restricted Export Alternative
Corn grain (bu.)	107.4	104.2	84.0
Sorghum grain (bu.)	59.2	50.8	50.6
Barley (bu.)	57.9	52.6	58.6
Oats (bu.)	67.6	55.0	57.8
Wheat (bu.)	37.1	32.8	34.1
Corn silage (tons)	16.4	14.4	11.3
Sorghum silage (tons)	14.4	12.8	10.3
Legume hay (tons)	4.1	4.0	4.0
Nonlegume hay (tons)	2.3	1.8	2.0
Soybeans (bu.)	34.0	33.0	32.6
Cotton (bales)	1.6	1.6	1.2

Regional production of crops and livestock in the High Export Alternative

Regional crop production patterns are stable under the High Export Alternative except for a relatively large increase of corn and sorghum production in the Northern Plains. However, the Corn Belt and the Lake States remain the principal producers of corn and sorghum (Table 43). Small grain production declines in most regions and in total. Wheat production, however, increases by 18 percent because of its role as an export crop. Oilmeal production increases in all but one region with about one-half of total production concentrated in the Corn Belt. Cotton production increases in the Delta States region in the High Export Alternative compared to the Base Alternative.

As the result of crop production changes, the livestock industry is forced to make adjustments. Other feeds are substituted for small grains in the livestock ration to free more wheat for export (Table 44). The feeding of wheat declines by 80 percent under the High Export Alternative as compared to the Base Alternative.

The increase in corn and sorghum production in the Northern Plains favors swine production in this region as hogs shift to it from the Corn Belt (Table 45). Beef feeding replaces some hogs in the Corn Belt region in the High Export Alternative. Beef cattle displaced by hogs in the Northern Plains shift to the Southern Plains.

Soil erosion in the High Export Alternative

Soil management practices also shift in the High Export Alternative relative to the Base Alternative. Continuous row cropping increases as

Table 43a. Changes in regional production by crop in each reporting region for the High Export Alternative compared to the Base Alternative (1,000 units)[a]

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	150,322	-46,634	3,968	0	-874	6,121
Appalachian	-154,778	-34,216	114,797	-194	-889	5,073
Southeast	1,678	-24,824	11,624	-207	366	296
Lake States	387,637	-39,597	13,835	0	-8,421	1,490
Corn Belt	100,368	-93,318	208,666	0	-1,605	-37,955
Delta States	-48,584	-5,806	26,774	1,647	-1,216	4,659
Northern Plains	991,390	-94,605	147,387	0	2,565	-18,510
Southern Plains	15,575	-93,655	80,489	-466	16,918	23,048
Mountain	50,165	106,187	18	0	498	7,615
Southwest	11,227	-3,987	38	11	604	1,524
Northwest	0	66,726	5	0	3,562	4,693
Pacific	4,135	-13,822	-2,018	-691	9,376	7,816
United States	1,509,135	-388,642	605,691	104	20,883	5,834

[a]Positive values indicate an increase in production of the crop in the High Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 43b. Percentage changes in regional production by crop in each reporting region for the High Export Alternative compared to the Base Alternative[a]

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	43	-39	---	0	-10	66
Appalachian	-67	-13	-93	-100	-7	63
Southeast	---	-67	10	-10	3	---
Lake States	20	-30	10	0	-38	49
Corn Belt	4	-47	29	0	-6	-56
Delta States	-48	-36	16	29	-11	29
Northern Plains	660	-8	839	0	5	-26
Southern Plains	3	-25	240	-43	18	12
Mountain	339	63	.5	0	6	223
Southwest	---	-24	3	2	7	11
Northwest	0	58	29	0	107	57
Pacific	22	-14	-52	-54	71	62
United States	25	-14	46	1	8	1

[a]Positive values indicate an increase in production of the crop in the High Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

the production of corn, sorghum, and soybeans for export expands (Table 46). The number of acres protected by strip cropping and terracing rises in the High Export Alternative because of the increased row cropping of land especially susceptible to soil erosion compared to the Base Alternative (Table 47). Because of the large increase in cultivated acres not protected by adequate soil conservation practices, total soil erosion increases by 21 percent in the High Export Alternative.

Table 44. Percentage distribution of feedstuffs by weight consumed by all classes of livestock in the Base, High Export, and Restricted Export Alternatives

	Base Alternative	High Export Alternative	Restricted Export Alternative
Corn and sorghum grain	11	11	13
Barley, oats and wheat	2	1	3
Oilmeals	3	3	2
Legume and non-legume hay	33	35	47
Corn and sorghum silage	51	51	35

Restricted Export Alternative

Resource use in the Restricted Export Alternative

The requirement that the environmental impact of agricultural production activities be controlled results in a substantial decline in potential export capacity in the Restricted Export Alternative compared to the High Export Alternative (Table 40). Reduced export capacity under the Restricted Export Alternative is due in part to reduced land

Table 45. Changes and percentage changes in the regional distribution of livestock in each reporting region between the High Export Alternative and the Base Alternative (1,000 head in animal numbers and percentages)[a]

Region	Beef cows	% change	Beef feeding	% change	Dairy-ing	% change	Hogs	% change
New England	0	0	607	77	0	0	0	0
Appalachian	337	33	-176	-16	-560	-29	0	0
Southeast	-129	-13	89	6	521	47	0	0
Lake States	-620	-52	-563	-50	0	0	2,616	7
Corn Belt	-1,923	-28	2,469	35	0	0	-16,669	-30
Delta States	31	1	126	11	0	0	0	0
Northern Plains	-2,143	-18	-829	-12	0	0	14,053	65
Southern Plains	3,164	13	3,056	18	39	3	0	0
Mountain	837	45	741	56	0	0	0	0
Southwest	383	17	-493	-28	-45	-28	0	0
Northwest	244	34	212	31	0	0	0	0
Pacific	1,868	98	1,122	71	0	0	0	0

[a]Positive values indicate an increase in animal numbers in the High Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 46. Comparison of percentage distribution of row crop acres by rotation in the Base, High Export, and Restricted Export Alternatives

Model	Percent of rotation sequence that is row cropping			
	25	50	75	100
Base Alternative	18	29	11	41
High Export Alternative	17	20	15	46
Restricted Export alternative	31	25	20	22

Table 47. Comparison of the proportion of acres by conservation practice in the Base, High Export, and Restricted Export Alternatives

Conservation practice	Proportion of acres		
	Base Alternative	High Export Alternative	Restricted Export Alternative
Straight row and contour farming	92	81	75
Strip cropping and terracing	8	19	25

utilization. Cropland having severe erosion problems is not cropped in the Restricted Export Alternative. This alternative also has considerable tillable land which is not cropped because of the nitrogen restriction. The nitrogen restriction reduces crop yields to the extent that many acres of marginal land do not produce enough to cover the cost of required soil conservation practices. This marginal land is not evenly distributed across the United States. Thus, the percentage of available cropland that is cropped declines in some regions more than others in comparison with the High Export Alternative (Table 48).

Although the Restricted Export Alternative uses less land and nitrogen that the High Export Alternative, it uses more land than the Base Alternative. Land planted to crops under the Restricted Export Alternative exceeds that of the Base Alternative by 55 million acres. Pesticide expenditures also increase by 80 percent under the Restricted Export Alternative as compared to the Base Alternative. Because of the nitrogen restriction policy, however, nitrogen use is 12 percent less than under the Base Alternative.

Table 48. Percentage of land available for crops that are cropped in the Base, High Export, and Restricted Export Alternatives

Region	Base Model	High Export Alternative	Restricted Export Alternative
New England	95	100	95
Appalachian	76	97	94
Southeast	96	99	97
Lake States	94	100	99
Corn Belt	89	100	96
Delta States	86	96	91
Northern Plains	67	98	94
Southern Plains	81	99	97
Mountain	81	97	96
Southwest	86	99	99
Northwest	76	97	95
Pacific	77	97	95
United States	82	99	96

The combination of reduced nitrogen use and the soil conservation restraint alters resource use by commodity groups in the Restricted Export Alternative compared to the Base Alternative (Table 49). The changes shown in Table 49 are the result of both lower yields resulting from the nitrogen restraint and changes in regional location of production.

Table 49. Quantity and percentage change of output and inputs by commodity groups in the Restricted Export Alternative compared to the Base Alternative

	Commodity Group					
	Corn and sorghum grain	Barley, oats, and wheat	Cotton	Soybeans	Legume and non-legume hay	Corn and sorghum silage
<u>Production</u>						
1,000 units	506,017	330,938	104	19,126	70,010	-163,794
Percent	8	12	1	7	26	-40
<u>Cropland acres</u>						
1,000 acres	24,836	10,758	2,192	9,363	25,902	-4,533
Percent	41	17	32	12	74	-16
<u>Nitrogen use</u>						
1,000 tons	-746	113	-221	296	91	-467
Percent	-21	7	-67	190	11	-44
<u>Pesticide expenditures</u>						
1,000 dollars	299,598	52,100	32,220	415,198	31,271	-5,288
Percent	86	86	22	113	628	-8

<u>Production of crops and livestock in the Restricted Export Alternative</u>

The expansion of crop production in the Restricted Export Alternative is greatly influenced by erosion problems in four regions of the United States: the Corn Belt, the Delta States, the Southeast, and the Appalachian regions (Table 50). For example, a considerable shift of corn, sorghum, and soybeans to the Northern Plains occurs because this region has fewer erosion problems. These crops replace some small grains produced in the Northern Plains in the Base Alternative. The small grains then shift to certain sections of the Corn Belt which have a relatively high erosion hazard. Similarly, cotton production shifts to areas with fewer erosion problems. Production declines in the Appalachian, the Southeast, and the Delta States regions and increases in the Southern Plains.

Table 50a. Changes in regional production by crop in each reporting region between the Restricted Export Alternative and the Base Alternative (1,000 units)[a]

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-94,863	75,755	4,450	0	135	-4,934
Appalachian	-4,742	-78,115	28,592	-194	10,205	35
Southeast	64,586	12,837	-86,008	-727	5,319	-13,630
Lake States	-112,393	13,686	30,980	0	-5,463	200
Corn Belt	-213,544	465,283	-107,706	0	10,143	-56,778
Delta States	-90,868	208,033	-37,710	-1,488	-573	-16,095
Northern Plains	1,104,955	-355,941	183,462	0	12,286	-21,544
Southern Plains	-93,286	-1,010	75,438	1,427	18,431	-64,922
Mountain	31,932	29,793	30	0	4,780	232
Southwest	10,665	6,396	1,864	619	803	-12,370
Northwest	-82,901	45,535	14	0	3,993	8,991
Pacific	-13,619	30,395	1,902	466	9,950	-10,237
United States	505,917	330,938	92,312	104	70,010	-163,794

[a]Positive values indicate an increase in production of the crop in the Restricted Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

Table 50b. Percentage changes in regional production by crop in each reporting region between the Restricted Export Alternative and the Base Alternative[a]

Region	Corn and sorghum grain (bu.)	Barley, oats, and wheat (bu.)	Oilmeal (cwt.)	Cotton (bales)	Legume and nonlegume hay (tons)	Corn and sorghum silage (tons)
New England	-27	64	---	0	2	53
Appalachian	-2	-29	23	-100	83	.4
Southeast	---	34	-72	-34	47	---
Lake States	-6	10	22	0	-25	7
Corn Belt	-8	234	-15	0	37	-84
Delta States	-90	1,299	-23	-26	-5	-100
Northern Plains	736	-30	1,044	0	25	-31
Southern Plains	-17	-.3	225	131	19	-33
Mountain	216	18	83	0	59	7
Southwest	---	39	131	132	9	-89
Northwest	-100	40	82	0	120	109
Pacific	-72	30	49	36	76	-82
United States	8	12	7	1	26	-40

[a]Positive values indicate an increase in production of the crop in the Restricted Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

The environmental restraints of the Restricted Export Alternative also cause a decline in both acres and production of silage. Consequently, hay production increases and is substituted for silage in the livestock rations (Table 44).

The ration changes are not adequate to compensate for the regional crop production changes in the Restricted Export Alternative. Hence, livestock production shifts among regions (Table 51). Hog production shifts away from the Corn Belt to the Northern Plains and the Lake States because of the regional shifts in corn production. Both the Corn Belt and the Delta States regions have fewer feeder cattle because corn grain and corn silage acreage is reduced to lessen soil erosion. These displaced feeders are dispersed across the United States with the largest number going to the Pacific region. The new crop mix for the Appalachian region in the Restricted Export Alternative causes an expansion of its beef cattle industry and a decline in swine production compared to the Base Alternative.

Soil erosion in the Restricted Export Alternative

As compared to the Base Alternative, the cropping practices required by the environmental restraints in the Restricted Export Alternative have a substantial impact on soil erosion. Soil erosion declines by 49 percent compared to the Base Alternative even though 55 million additional acres are cropped in the Restricted Export Alternative. This large decline in soil erosion occurs because of the expanded use of rotations with hay and small grains and greater strip cropping and terracing to protect the soil

Table 51. Changes and percentage changes in the regional distribution of livestock in each reporting region between the Restricted Export Alternative and the Base Alternative[a]

Region	Beef cows	% change	Beef feeding	% change	Dairy-ing	% change	Hogs	% change
New England	22	---	-98	-12	-297	-14	0	0
Appalachian	2,005	194	520	47	-389	-20	-1,080	-41
Southeast	675	66	900	61	400	36	0	0
Lake States	-550	-46	-61	-5	292	20	11,481	31
Corn Belt	-466	-7	-1,467	-21	0	0	-32,513	-59
Delta States	564	28	-1,179	-100	-74	-10	0	0
Northern Plains	-498	-4	849	13	0	0	22,113	103
Southern Plains	-1,824	-7	573	3	43	4	0	0
Mountain	995	53	621	47	0	0	0	0
Southwest	-874	-38	-946	-53	-48	-30	0	0
Northwest	613	85	532	79	0	0	0	0
Pacific	1,613	84	1,109	70	0	0	0	0

[a]Positive values indicate an increase in animal numbers in the Restricted Export Alternative compared to the Base Alternative. Negative values have the opposite meaning.

(Tables 46 and 47). Significant improvement in erosion rates occurs in the Appalachian, the Southeast, the Corn Belt, and the Delta States regions (Table 52).

Trade-Offs Between the Export Alternatives

Comparing the two export alternatives shows the trade-offs between agricultural exports and environmental quality. The production of commodities declines in the Restricted Export Alternative compared to the High Export Alternative because the environmental restraints make crop production unprofitable on 12.6 million acres. Production also declines because of lower yields caused by the environmental restraints which decreased total nitrogen use by 30 percent. As a result of the reduced production, total exports, measured in dollar terms, fall by 40 percent in the Restricted Export Alternative. Because the Restricted Export Alternative crops fewer acres and uses more soil-conserving farm practices, such as terracing, total soil erosion decreases by 160 percent relative to the High Export Alternative.

Table 52. Comparison of average rates of soil erosion by reporting region in the Base, High Export, and Restricted Export Alternatives

	Soil loss per acre (tons per annum)		
Region	Base Model	High Export Model	Restricted Export Model
New England	5.9	6.8	2.2
Appalachian	5.5	8.7	2.1
Southeast	11.0	11.0	3.3
Lake States	3.3	3.3	2.4
Corn Belt	8.8	8.2	2.6
Delta States	5.2	6.3	3.0
Northern Plains	1.1	1.7	1.5
Southern Plains	3.7	3.3	1.9
Mountain	4.6	2.5	1.7
Southwest	.9	1.2	.9
Northwest	1.9	3.1	1.7
Pacific	.8	.8	.8
United States	5.0	4.9	2.1

Restricting nitrogen applications and requiring expensive soil-conserving farm practices reduces the value of cropland. The environmental restrictions in the Restricted Export Alternative raise the cost of producing crops and lower the income potential of cropland, resulting in a 25 percent decline in the shadow price of cropland as compared to the unrestricted High Export Alternative.

X. SUMMARY

This report is one in a sequence published by the Center for Agricultural and Rural Development (CARD) under a grant from the National Science Foundation's Research Applied to National Needs (RANN) program concerned with policies for resource use in agriculture. The objective of this report is the analysis of policies designed to curb pollution problems created by excessive erosion of the soil, persistence of certain organochlorine insecticides in the environment, feedlot runoff, and the pollution of water supplies with nitrates.

The Model

The policy studies in this report are conducted using an interregional linear programming model of U.S. agriculture. The land resources are divided into producing areas representing homogenous production conditions. Crop and livestock production activities are defined within these producing areas. The model has 105 producing areas and 28 market regions. There are five land classes in each producing area. It incorporates a transportation submodel linking all regions. The demands for the commodities are defined in the market regions according to per capita consumption and population projections. When the model is solved the land in each producing area is brought into crop production under the criterion of minimum cost, i.e., the most productive land is utilized first. This procedure allocates the production of crops and livestock to each of the producing areas to minimize the total cost of production and transportation incurred while meeting the demands for agricultural products projected for the year 1985. It also provides a competitive equilibrium in the sense that all resources except land receive their market rate of return. Return to land is determined endogenously in the model.

Alternative Futures

Six alternative futures are analyzed in this study to determine the effect conservation and environmental improvement policies might have on U.S. agriculture. The alternatives analyzed are: (1) Base Alternative where ongoing trends are assumed and no environmental restraints are imposed; (2) Soil Conservation Alternative where ongoing trends are the same as in the Base Alternative but soil erosion is restricted; (3) Nitrogen Restriction Alternative where ongoing trends are the same as in the Base Alternative but no more than 50 pounds of nitrogen can be applied per acre on any crop; (4) Insecticide Restriction Alternative where ongoing trends are the same as in the Base Alternative but farmers are denied the use of the organo-chlorine insecticides Chlordane and Heptachlor; (5) Feedlot Runoff Control Alternative where ongoing trends are the same as in the Base Alternative but feedlot operators are required to control the runoff from their feedlots; (6) High Export Alternative where all cropland is planted to crops but no environmental restraints are imposed; and (7) Restricted Export Alternative where the soil loss, nitrogen and insecticide restrictions and the feedlot runoff control are the same as in the other alternatives outlined above. The same model is used in analyzing each of these seven alternatives.

Soil Conservation Alternative

Soil scientists estimate that the amount of soil that can be lost by erosion without impairing the future productivity of agriculture varies from one ton per acre per year on shallow soils to five tons on deep soils. A policy requiring agriculture to limit soil erosion to these levels eliminates those cropping alternatives which do not provide adequate protection for the soil.

The analysis of this soil conservation policy indicates that agriculture has the capacity to comply by changing cropping practices to include more reduced tillage, more strip cropping and terracing, and less continuous row cropping.

The changes in cropping practices result in regional shifts in crop and livestock production. Small grain and hay production increase substantially in the Corn Belt offsetting a declining production of the row crops: corn, sorghum, and soybeans. This substitution of crops is needed because of the erosion problems caused by row cropping. The smaller erosion problems of the Northern Plains favors the production of corn, sorghum, and soybeans. For the same reason, cotton production shifts some from the Appalachian and Southeast regions to the Pacific region.

Beef cattle replace hogs to an extent in the Corn Belt because of the substitution of hay for corn production. Most of the displaced hogs move to the Northern Plains because of the region's increased feed grain production in the Soil Conservation Alternative. The beef cattle industry declines in the Northern Plains. Both beef cattle and hog production increase in the Appalachian region.

These shifts result in a moderate increase in the total value of agricultural commodities produced in the Corn Belt and Lake States regions and a substantial increase in the Appalachian and Northern Plains regions.

In comparison with the Base Alternative, results for the Soil Conservation Alternative indicate that total soil erosion might be reduced by 55 percent when agriculture complies with the soil conservation policy. However, to continue to meet domestic and foreign commodity demands an additional 15 million acres of land must be planted to crops. Also, agriculture needs to use 14 percent more nitrogen and 7 percent more pesticides. This increase in the use of resources is needed to compensate for declining crop yields as crop production moves to regions of lower productivity, particularly as corn and soybean production shifts from the Corn Belt to the Northern Plains. A consequence of these production shifts to areas of lower productivity is rising supply prices, especially for soybeans.

The changes in farming practices indicated by the analysis require new management skills and more capital investments by farmers. Shifting from conventional tillage to reduced tillage creates new weed and insect problems and constructing terraces requires substantial capital investments in the land.

The results from the analysis also imply capital gains and losses for current landowners. The return to land subject to excessive erosion falls because of the additional expense of controlling soil erosion and land not subject to excessive erosion has a higher return.

Higher returns to land occur in the Appalachian, Lake States, and Delta States regions. Regions which have reductions in land returns as a result of conservation policy are the New England, Southeast, Southern Plains, and Northwest regions.

Nitrogen Restriction Alternative

A policy restricting the use of nitrogen in agriculture to 50 pounds per acre to reduce the possibility of nitrate pollution results in lower crop yields. Lower yields require more land for crops to maintain the total output of agriculture and alter regional production patterns. Corn production decreases in the Corn Belt and the Appalachian regions while small grain, hay, and silage production increases. In response to the changed crop mix, beef cattle are substituted partially for hogs in the Corn Belt and Appalachian regions. Some hogs shift into the Lake States and Northern Plains regions. The result of these and other shifts is a substantial increase in the total value of agricultural commodities produced in the Appalachian, Lake States, Corn Belt, and Northern Plains regions in the Nitrogen Restriction Alternative compared to the Base Alternative.

In comparison to the Base Alternative, the Nitrogen Restriction Alternative reduces total nitrogen use by 26 percent, but requires that 25 million additional acres be cultivated and that pesticide expenditures increase by 8 percent to compensate for lower crop yields. Because these additional acres are of lower productivity and because 50 pounds of nitrogen per acre is less than the economic optimum for some crops the supply prices for farm commodities rises, especially for cotton.

Individual farmers with all their cropland in production would be unable to substitute land for nitrogen to offset declining yields. Hence, they would realize reduced total production per farm. This possibility of lower farmer income is most important for selected farmers producing corn, sorghum, and cotton in several locations.

The results from the analysis also imply capital gains and losses for current landowners. As per acre production declines and regional crop production patterns are altered, the returns to land changes. Land returns increase most in the New England, Appalachina, Southwest, and Lake States regions and decline in the Southwest and Pacific regions.

Insecticide Restriction Alternative

Banning the agricultural use of Chlordane and Heptachlor under the Insecticide Restriction Alternative affects corn production, especially in the Midwest. Substitutes for these insecticides are more expensive and equally effective except for two insect problems. These insect problems are the first year insect complex of wireworms and grubs in corn following a grass crop and cutworm damage to corn grown in lowland areas.

In comparison with the Base Alternative, agriculture adjusts to the insecticide substitutes by replacing corn production in the lowland areas with soybeans and small grains and by reducing the acres of first year corn following grass. The additional costs of corn production in the Midwest cause a slight shift of corn production away from the Corn Belt and a replacement of it by small grains and soybeans.

The results indicate few major changes in total resource use in agriculture or in the supply prices of commodities, including corn, under the Insecticide Restriction Alternative. However, these small adjustments do not account for the losses that will be incurred by some corn producers. On the average, the crop losses are small, but because insect damage may range from zero to a total loss, there is the possibility that the incomes of some farmers may be significantly reduced by a ban on Heptachlor and Chlordane.

Feedlot Runoff Control Alternative

Requiring feedlot operators to control the runoff from their feedlots to reduce pollution of nearby waterways raises the cost of livestock production. The increase in costs varies with regional differences in average size of livestock enterprises, the proportion of livestock in feedlots whose runoff may enter a waterway, and climate. When these costs are included in the model for the Feedlot Runoff Control Alternative, there is a slight shift of beef cattle from the Lake States to the Corn Belt and from the Northern Plains to the Southern Plains. There also is a small shift of hog production from the Corn Belt to the Northern Plains.

Comparison of the results from the Feedlot Runoff Control Alternative with the Base Alternative indicates few important changes in total resource use in agriculture or in the supply prices of commodities, including beef and pork. The small increase in the shadow price of livestock products does not mean that all livestock producers would be unaffected. Because of the expense for runoff control facilities, farmers will be earning a lower rate of return than expected on their investments in feedlot facilities. Small operators would be most affected because the cost of runoff control facilities increases sharply with decreasing lot size.

Export Potential Alternatives

The purpose of this alternative is to analyze the impact of higher production costs caused by environmental restraints on the potential export capacity of U.S. agriculture. Higher production costs decrease the export capacity of agriculture because marginal land, formerly profitable to crop, is taken out of production.

The analysis requires the development of two export alternatives, both allowing the exports of corn, wheat, oilmeal, and sorghum to expand until production costs equal a predetermined export price. The first alternative, the High Export Alternative, is formulated with an export price high enough to bring almost all the available cropland into production. This expanded use of cropland is made without consideration of environmental consequences. The second alternative, the Restricted Export Alternative, is formulated to require that agriculture complies with the four environmental restraints reviewed earlier as output increases. Because each of the restraints raises production costs, the effect of compliance is to lower the potential export capacity of U.S. agriculture as shown in Table 53.

High Export Alternative

The High Export Alternative uses 67 million more acres than does the Base Alternative. However, the expansion of exports shown in

Table 53. Comparison of export levels for the three models

Commodity	Export quantities (1,000 tons) Base Alternative	High Export Alternative	Restricted Export Alternative
Corn	27,692	60,844	37,005
Wheat	23,220	37,764	27,306
Oilmeal	22,562	52,406	30,946
Sorghum	4,480	9,255	5,821

Table 53 requires more than land. The High Export Alternative uses 29 percent more nitrogen and increases pesticide expenditures by 50 percent. Most of the nitrogen increase is due to the high requirements of corn and sorghum. The largest proportion of the increase in pesticide expenditures is for corn, sorghum, and soybeans.

Regional crop production patterns are stable except for a relatively large increase of corn and sorghum in the Northern Plains and an increase in the concentration of cotton production in the Delta States region. The increase in corn and sorghum production in the Northern Plains favors swine production as hogs shift from the Corn Belt to the Northern Plains. Beef feeding partially replaces the hogs in the Corn Belt region in the High Export Alternative. Beef cattle displaced by hogs in the Northern Plains shift to the Southern Plains.

The soil management practices change in the High Export Alternative relative to the Base Alternative. Continuous row cropping increases as the production of corn, sorghum, and soybeans for export expands. The number of acres protected by strip cropping and terracing rises in the High Export Alternative because of the increased row cropping of land especially susceptible to soil erosion compared to the Base Alternative. Because of the large increase in cultivated acres not protected by soil conservation practices, total soil erosion increases by 21 percent in the High Export Alternative as an average for the United States.

Restricted Export Alternative

The reduced export capacity of the Restricted Export Alternative relative to the High Export Alternative is due partly to reduced land utilization since cropland having severe soil erosion problems is not cropped. The Restricted Export Alternative also has considerable tillable land which is not cropped. The nitrogen restriction reduces crop yields to the extent that many acres of marginal land cannot produce enough to cover the cost of the required soil conservation practices. As the result of these factors, there is a considerable shift of corn, sorghum, and soybean production from the Corn Belt to the Northern Plains where fewer erosion problems exist. These crops replace the small grains produced in the Northern Plains in the Base Alternative. Some small grains shift to the Corn Belt to reduce the erosion hazard.

Hog production shifts partly away from the Corn Belt to the Northern Plains and the Lake States in line with changes in corn production. Both the Corn Belt and the Delta States regions feed fewer cattle because of the erosion hazard of growing the corn grain and corn silage to feed them. These displaced feeders are dispersed across the United States with the largest number going to the Pacific region.

Soil erosion declines by 49 percent compared to the Base Alternative even though 55 million additional acres are cropped in the Restricted

Export Alternative. This significant decline in soil erosion occurs because of expanded use of rotations with hay and small grains and the increased use of strip cropping and terracing to protect the soil.

High Export Alternative compared to the Restricted Export Alternative

Imposing the environmental restraints on agriculture in the Restricted Export Alternative reduces the dollar value of exports by 40 percent, thus affecting the trade position of the United States. The environmental restraints make crop production unprofitable on 12.6 million acres of available cropland. They also cause a 25 percent decline in land return as compared to the High Export Alternative. A 60 percent decline in soil erosion and a 30 percent reduction in nitrogen used for crop production in the Restricted Export Alternative as compared to the High Export Alternative imply improved water quality and greater soil conservation.

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